NFPA 402

1996 Edition

Guide for Aircraft Rescue and Fire Fighting Operations

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This edition of NFPA 402, *Guide for Aircraft Rescue and Fire Fighting Operations*, was prepared by the Technical Committee on Aircraft Rescue and Fire Fighting and acted on by the National Fire Protection Association, Inc. at its Annual Meeting held May 20–23, 1996 in Boston, MA. It was issued by the Standards Council on July 18, 1996, with an effective date of August 9, 1996, and supersedes all previous editions.

Changes other than editorial are indicated by a vertical rule in the margin of the pages on which they appear. These lines are included as an aid to the user in identifying changes from the previous edition.

This edition of NFPA 402 was approved as an American National Standard on July 26, 1996.

Origin and Development of NFPA 402

These standard operating procedures were first developed by the sponsoring NFPA committee in 1947 and were first adopted by the Association in 1951. They were amended in 1969 and 1973. In 1984, the Committee combined the text of NFPA 406M, *Manual on Aircraft Rescue and Fire Fighting Techniques for Fire Departments Using Structural Fire Apparatus and Equipment*, with the text of NFPA 402, *Recommended Practice for Aircraft Rescue and Fire Fighting Operational Procedures for Airport Fire Departments*, and reidentified the document as NFPA 402M. The entire texts of both NFPA 402 and NFPA 406M were revised to create NFPA 402M. The 1989 edition of NFPA 402M was a complete revision of the manual. This guide was revised again in 1991.

The aircraft figures were deleted for the 1996 edition. A comprehensive collection of figures is now available in a publication titled *NFPA Aircraft Familiarization Charts Manual*.

Task Group on Aircraft Rescue and Fire Fighting Operational Procedures

Edward B. (Ned) Aksim, Consultant, PA; John Cedric Black, BAA plc, England; Brian Boucher, Canadian Air Line Pilots Assn., ON, Canada; Derek K. G. Dodwell, Civil Aviation Authority, England; Robert J. Donahue, Massport, MA; Vic Hewes, Airport Safety Services, GA; Noreene Koan, Assn. of Flight Attendants, CA; Jack McComb, Quality Fire Mgmt., NV;

John J. O'Sullivan, British Airways, England; Davis R. Parsons, Los Angeles City Fire Dept., CA; Richard M. Radford, The Fire Service College, England; Robert G. Relyea, ARFF Working Group, TX; Robert E. Reyff, Dallas, TX; Robert W. Rice, Air Force Flight Test Center, CA; John M. Schuster, 3M Co., MN; Bernard Valois, Safety & Technical Services Directorate, Canada; A. R. Villegas, U.S. Navy, CA; Pam Walden, The Port Authority of NY & NJ, NY; Ronald O. Wikander, Lockheed Aeronautical Systems Co., GA; Larry E. Williams, Emergency Response Training Academy, Inc., AR; Richard G. Winnie, Westinghouse Electro-Optical Systems, FL; Joseph A. Wright, FAA Technical Center, NJ; Joe Ybarra, U.S. Air Force, FL.

Technical Committee on Aircraft Rescue and Fire Fighting

Brian Boucher, *Chair*
Canadian Air Line Pilots Assn., Canada
Rep. Canadian Air Line Pilots Assn.

Robert J. Donahue, *Secretary*
Massport Fire Dept., Logan Int'l Airport, MA

John Cedric Black, BAA plc, Heathrow Airport Ltd, England

Booker T. Burley, Hartsfield Atlanta Int'l Airport, GA

Ralph Colet, John Russo Industrial Inc., CA

Robert L. Darwin, U.S. Dept. of the Navy, DC

Derek K. G. Dodwell, Civil Aviation Authority, England

Fred B. Goodnight, Amerex Corp., AL
Rep. Fire Equipment Mfrs. Assn. Inc.

B. V. Hewes, Airport Safety Services, GA

Paul O. Huston, Paul O. Huston, PE & Assoc., AL

D. Steve Kiernan, Nat'l Foam, Inc., PA

L. M. Krasner, Factory Mutual Research Corp., MA

Dave Lenz, Oshkosh Truck Corp., WI

John J. O'Sullivan, British Airways, England

Davis R. Parsons, Los Angeles City Fire Dept., CA

Nonvoting

Gary Hammack, U.S. Nat'l Transportation Safety Board, DC
(Alt. to L. D. Roman)

Thomas J. Lett, Albuquerque Fire & Safety Assoc. Inc., NM
(Member Emeritus)

Paul J. Lindsay, Transport Canada, Ottawa, Canada
(Alt. to B. Valois)

John E. Lodge, Lodge Fire Protection Consultancy Ltd, England
(Member Emeritus)

James F. O'Regan, Westboro, MA
(Member Emeritus)

Lawrence D. Roman, U.S. Nat'l Transportation Safety Board, DC

David F. Short, Carmichael Int'l Ltd, England

Bernard Valois, Transport Canada, Ottawa, Canada

Mark T. Conroy, NFPA Staff Liaison

This list represents the membership at the time the Committee was balloted on the text of this edition. Since that time, changes in the membership may have occurred.

NOTE: Membership on a Committee shall not in and of itself constitute an endorsement of the Association or any document developed by the Committee on which the member serves.

Committee Scope: This Committee shall have primary responsibility for documents on aircraft rescue and fire fighting services and equipment, for procedures for handling aircraft fire emergencies, and for specialized vehicles used to perform these functions at airports, with particular emphasis on saving lives and reducing injuries coincident with aircraft fires following impact or aircraft ground fires. This Committee also shall have responsibility for documents on aircraft fire investigation procedures as an aid to accident prevention and the saving of lives in future aircraft accidents involving fire.

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NOTICE: Information on referenced publications can be found in Chapter 13 and Appendix F.

Chapter 1 Administration

1-1 Scope.

1-1.1

This guide provides information relative to aircraft rescue and fire fighting operations and procedures for airport and structural fire departments. These procedures deal with aircraft not involved in military operations. They can, however, be generally applicable to military aircraft not operating in an armament mode. For specific guidance in these matters, consult the commander or fire chief of the nearest military air installation.

1-1.2

Statistics indicate that approximately 80 percent of all major commercial aircraft accidents occur in the critical rescue and fire fighting access area. This is the primary response area for airport-based ARFF services. Approximately 15 percent of the accidents occur in the approach areas. In such instances the community/mutual services could be the prime responders.

1-1.3

Some airport fire departments have the total fire prevention and fire protection responsibility for the entire airport, including structural fire fighting responsibilities in terminal buildings, aircraft hangars, airport hotels, cargo buildings, and other facilities. Procedures for these fire prevention and protection operations are not covered in this guide.

1-2 Purpose.

1-2.1

This guide has been prepared for the use and guidance of those charged with the responsibility of providing and maintaining aircraft rescue and fire fighting (ARFF) services on airports.

1-2.2

The guide's content is also intended for the use of structural fire departments to assist them in developing methods to effectively handle aircraft incidents that might occur within their jurisdiction. It also provides for a basis of understanding, relative to emergencies on airports, that would enhance structural fire departments’ effectiveness when called to assist airport fire departments.

1-3 General.

1-3.1

Providing protection for the occupants of an aircraft takes precedence over all other operations. Fire control is frequently an essential condition to ensure such survival. The objectives of the airport fire department should be to respond to any aircraft emergency in the minimum possible time and employ rescue and fire fighting techniques effectively. These objectives can be accomplished when properly trained personnel work together as a team and apply the operational procedures presented in this guide.

1-3.2

Governmental and organizational publications frequently referenced in this guide can be found in Chapter 14.

1-3.3

If a value for measurement as given in this guide is followed by an equivalent value in other units, the first stated is to be regarded as the requirement. A given equivalent value might be approximate.

1-3.4

Metric units of measurement in this guide are in accordance with the modernized metric systems known as the International System of Units (SI). One unit (liter), outside of, but recognized by SI, is commonly used in international fire protection.

1-4 Definitions.

Air Accident Investigations Branch (AAIB). A UK agency that is responsible for investigating and determining the probable cause of all British aircraft accidents.

Air-Cushioned Vehicle (ACV). A vehicle that can travel on land and water.

Aircraft Accident. An occurrence during the operation of an aircraft in which any person involved suffers death or serious injury or in which the aircraft receives substantial damage.

Aircraft Accident Pre-Incident Planning. This term is used to describe the process of forecasting all factors that could possibly exist involving an aircraft accident that could bear upon the existing emergency resources. A pre-incident plan should define the emergency organizational authority and the responsibilities of all those involved.

Aircraft Defueling. See Fuel Servicing.

Aircraft Familiarization. Refers to the knowledge of vital information that rescue and fire fighting personnel should learn and retain with regard to the specific types of aircraft that normally use the airport and other aircraft that might use the airport due to weather conditions at scheduled destinations.

Aircraft Fire Fighting. The control or extinguishment of fire adjacent to or involving an aircraft following ground accidents/incidents. Aircraft fire fighting does not include the control or extinguishment of airborne fires in aircraft.

Aircraft Incident. An occurrence, other than an accident associated with the operation of an aircraft, that affects or could affect continued safe operation if not corrected. An incident does not result in serious injury to persons or substantial damage to aircraft.

Aircraft Rescue and Fire Fighting (ARFF). The fire fighting action taken to prevent, control, or extinguish fire involved or adjacent to an aircraft for the purpose of maintaining maximum escape routes for occupants using normal and emergency routes for egress. Additionally, ARFF personnel will enter the aircraft to provide assistance to the extent possible in the evacuation of the occupants. Although life safety is primary to ARFF personnel, responsibilities such as fuselage integrity and salvage should be maintained to the extent possible.

Airport (Aerodrome). An area on land or water that is used or intended to be used for the landing and takeoff of aircraft and includes buildings and facilities.

Airport Air Traffic Control (ATC). A service established to provide air and ground traffic control for airports.

Airport Familiarization. Refers to the knowledge that rescue and fire fighting personnel must maintain relative to locations, routes, and conditions that will enable them to respond quickly and efficiently to emergencies on the airport and those areas surrounding the airport.

Aluminum. A lightweight metal used extensively in the construction of aircraft airframes and skin sections.

Approved. Acceptable to the authority having jurisdiction.

NOTE: The National Fire Protection Association does not approve, inspect, or certify any installations, procedures, equipment, or materials; nor does it approve or evaluate testing laboratories. In determining the acceptability of installations, procedures, equipment, or materials, the authority having jurisdiction may base acceptance on compliance with NFPA or other appropriate standards. In the absence of such standards, said authority may require evidence of proper installation, procedure, or use. The authority having jurisdiction may also refer to the listings or labeling practices of an organization concerned with product evaluations that is in a position to determine compliance with appropriate standards for the current production of listed items.

Authority Having Jurisdiction. The organization, office, or individual responsible for approving equipment, an installation, or a procedure.

NOTE: The phrase "authority having jurisdiction" is used in NFPA documents in a broad manner, since jurisdictions and approval agencies vary, as do their responsibilities. Where public safety is primary, the authority having jurisdiction may be a federal, state, local, or other regional department or individual such as a fire chief; fire marshal; chief of a fire prevention bureau, labor department, or health department; building official; electrical inspector; or others having statutory authority. For insurance purposes, an insurance inspection department, rating bureau, or other insurance company representative may be the authority having jurisdiction. In many circumstances, the property owner or his or her designated agent assumes the role of the authority having jurisdiction; at government installations, the commanding officer or departmental official may be the authority having jurisdiction.

Auxiliary Power Unit (APU). A self-contained power source, provided as a component of an aircraft, that is used to energize aircraft systems when power plants are not operating or when external power is not available.

Backdraft. A phenomenon that occurs when a fire takes place in a confined area such as a sealed aircraft fuselage and burns undetected until most of the oxygen within is consumed. The heat continues to produce flammable gases, mostly in the form of carbon monoxide. These gases are heated above their ignition temperature and when a supply of oxygen is introduced, as when normal entry points are opened, the gases could ignite with explosive force.

Bogie. A tandem arrangement of aircraft landing gear wheels. The bogie can swivel up and down so that all wheels follow the ground as the attitude of the aircraft changes or the ground surface changes.

Cockpit Voice Recorder (CVR). A device that monitors flight deck crew communications through a pickup on the flight deck connected to a recorder that is usually mounted in the tail area of the aircraft and that is designed to withstand certain impact forces and a degree of fire.

COMBI. An aircraft designed to transport both passengers and cargo on the same level within the fuselage.

Command Post (CP). The location at the scene of an emergency where the Incident Commander is located and where command, coordination, control, and communications are centralized.

Composite Materials. Lightweight materials having great structural strength. They are made of fine fibers embedded in carbon/epoxy materials. The fibers are usually boron, fiberglass, aramid, or carbon in the form of graphite. Composite materials do not present unusual fire fighting problems, but products of their combustion should be considered a respiratory hazard to fire fighters.

Critical Rescue and Fire Fighting Access Area. The rectangular area surrounding any runway within which most aircraft accidents can be expected to occur on airports. Its width extends 500 ft (150 m) from each side of the runway centerline, and its length is 3300 ft (1000 m) beyond each runway end.

Dangerous Goods. This term is synonymous with the terms “hazardous materials” and “restricted articles.” The term is used internationally in the transportation industry and includes: explosives and any other article defined as a combustible liquid, corrosive material, infectious substances, flammable compressed gases, oxidizing materials, poisonous articles, radioactive materials, and other restrictive articles.

Deck Gun (Deluge Set). See Turret.

Departure. An aircraft taking off from an airport.

Dry Chemical. An extinguishing agent essentially consisting of a chemical salt with fire-inhibiting properties.

Dry Powder. An extinguishing agent suitable for use on combustible metal fires.

Empennage. The tail assembly of an aircraft, which includes the horizontal and vertical stabilizers.

Evacuation Time. The elapsed time between an aircraft accident/incident and the removal of all surviving occupants.

Evacuee. An aircraft occupant who has exited the aircraft following an accident/incident.

Exposure. Any person or property that could be endangered by fire, smoke, gases, or runoff.

Extinguishing Agent Compatibility. Related to the requirement that the chemical composition of each agent be such that one will not adversely affect the performance of other agents that might be used on a common fire.

Extinguishing Agent, Complementary. Refers to an extinguishing agent that has the compatibility to perform fire suppression functions in support of a primary extinguishing agent and where extinguishment might not be achievable using only the primary agent.

Extinguishing Agent, Primary. Agents that have the capability of suppressing and preventing the reignition of fires in liquid hydrocarbon fuels.

Extrication. The removal of trapped victims in an aircraft accident.

Federal Aviation Administration (FAA). An agency of the United States federal government charged with the primary responsibility of regulating aviation activities.

Fire Classifications.

Class A. Ordinary combustibles;

Class B. Flammable liquids;

Class C. Electrically charged components;

Class D. Combustible metals.

Fire Wall. A bulkhead designed to stop the lateral spread of fire in a fuselage or engine nacelle.

Flashback. The tendency of flammable liquid fires to re-ignite from any source of ignition after the fire has once been extinguished.

Flashover. All combustibles in a room or confined space have been heated to the point that they are giving off vapors that will support combustion, and all combustibles ignite simultaneously.

Flight Attendants. Those members of the flight deck crew whose responsibility includes the management of activities within the passenger cabin.

Flight Data Recorder (FDR). An instrument that monitors performance characteristics of an aircraft in flight. It is usually mounted in the tail area of an aircraft and is designed to withstand certain impact forces and a degree of fire. Its purpose is to provide investigators with flight performance data that might be relevant in determining the cause of an accident/incident.

Flight Deck Crew. Those members of the crew whose responsibility includes the management of the aircraft’s flight control and ground movements.

Flight Technical Crew (FTC). Includes pilots, flight engineers, and flight attendants who crew on aircraft movement.

Foam, Aqueous Film Forming Concentrate (AFFF). A concentrated aqueous solution of fluorinated surfactants and foam stabilizers that, when mixed with water and air in designated proportions, is capable of producing an aqueous fluorocarbon film on the surface of hydrocarbon fuels to prevent vaporization.

Foam, Film Forming Fluoroprotein (FFFP) Foam Concentrate. A concentrate that uses fluorinated surfactants to produce a fluid aqueous film for suppressing hydrocarbon fuel vapors. This type of foam also utilizes a protein base plus stabilizing additives and inhibitors to protect against freezing, corrosion, and bacterial decomposition, and it also resists fuel pickup.

Foam, Fluoroprotein. A protein-based foam concentrate to which fluorochemical surfactants have been added. This has the effect of giving the foam a measurable degree of compatibility with dry chemical extinguishing agents and an increase in tolerance to contamination by fuel.

Foam, Protein. A foam concentrate that uses protein as the basic foaming agent and is stabilized with metal salts to impart fire resistance to the foam blanket.

Foam Application Rate. The amount of foam solution in liters or gallons per minute expressed as a relationship with a unit of area, usually square meter or square foot.

Foam Blanket. A covering of foam over the surface of flammable liquids to provide extinguishment and prevent ignition.

Foam Burnback Resistance. The ability of a foam blanket to retain aerated moisture and resist destruction by heat and flame.

Foam Drain Time. The foam drain time — commonly the 25 percent drainage time (or $^1/_4$ drainage time) is the time required for 25 percent of the original foam solution (foam concentrate plus water) to drain out of the foam.

Forcible Entry. The act of making entry into an aircraft or other structure when normal entry points are not accessible.

Forward Looking Infrared (FLIR). A thermal imaging system (camera) which can be vehicle-mounted designed to detect thermal energy.

Frangible Gate/Fence. Gates or fence sections designed to open, break away, or collapse when struck with the bumper of an ARFF vehicle responding to an emergency.

Fuel Servicing. Fueling and defueling of aircraft fuel tanks, not including aircraft fuel transfer operations and design of aircraft fuel systems during aircraft maintenance or manufacturing operations.

Fuselage. The main body of an aircraft.

Grid Map. A map of an area overlaid with a grid system of rectangular coordinates that are used to identify ground locations where no other landmarks exist.

Halon. A liquefied gas extinguishing agent that extinguishes fire by chemically interrupting the combustion reaction between fuel and oxygen. Halon agents leave no residue.

Halon 1211. A Class ABC rated extinguishing agent that discharges as an 85 percent liquid that permits a long stream reach.

Halon 1301. An agent having ABC capability in total flooding systems and limited Class A capability when dispensed from portable extinguishers. The agent is discharged as a vapor.

Hazardous Materials. See Dangerous Goods.

Horizontal Stabilizer. That portion of an aircraft's structure that contains the elevators.

Hot Brakes. A condition in which the aircraft's brake and wheel components have become overheated, usually due to excessive braking during landing.

Ignition Temperature. The lowest temperature at which a fuel, when heated, will ignite in air and continue to burn.

Incident Commander (IC). The person in overall command at an emergency.

International Air Transport Association (IATA). An international group composed of the major airlines of the world that reviews aviation policy including safety items.

International Civil Aviation Organization (ICAO). An international aviation body, operating under the auspices of the United Nations, that produces technical safety documents for civil air transport.

Jet Blast. The thrust-producing exhaust from a jet engine.

Joint Aviation Authority (JAA). An agency in Europe charged with the responsibility of regulating safety in civil aviation.

Knockdown. A fire fighting term defining the reduction of flame and heat to a point where further extension of a fire has been abated and the overhaul stage can begin.

Magnesium. A silvery-white or grayish lightweight metal, two-thirds the weight of aluminum. Magnesium alloys are used in the construction of aircraft wheels, engine mounts, and various engine parts.

Main Gear. Refers to the two or more larger landing gear structures of an aircraft, as opposed to wing, nose, or tail gear assemblies.

Master Stream. A fire fighting water stream of large gallonage and extended reach delivered from a master stream appliance such as a deck gun.

Mechanical Ventilation. A process of removing heat, smoke, and gases from a fire area by using exhaust fans, blowers, air conditioning systems, or smoke ejectors.

Mutual Aid. Reciprocal assistance by emergency services under a prearranged plan.

National Transportation and Safety Board (NTSB). A federal agency that is responsible for investigating and determining the probable cause of aircraft accidents.

Nose Gear. That mechanical part of a landing gear system mounted under the nose of an aircraft. It can be designed either as a stationary component or one that retracts into the fuselage.

Overhaul. A fire fighting term involving the process of final extinguishment after the main body of a fire has been knocked down. All traces of fire must be extinguished at this time.

Penetrating Nozzle. An appliance designed to penetrate the skin of an aircraft and inject extinguishing agent.

Practical Critical Fire Area (PCA). This area is two-thirds of the Theoretical Critical Fire Area (TCA). (*See also Theoretical Critical Fire Area*.)

Preservation of Evidence. After an aircraft accident/incident it is imperative that investigative evidence be preserved after life safety and rescue operations have been concluded.

Pressurized Aircraft. Sealed, modern-type aircraft within which the internal atmospheric pressure can be regulated.

Protective Clothing. Fire fighters’ clothing including helmets, protective coats, protective trousers, boots, and gloves.

Rescue. Removal or assistance in the evacuation of occupants of an aircraft involved in an accident/incident or those persons exposed to such accident/incident.

Rescue Path. A fire-free path from an aircraft accident site to a safe area. This path, normally selected by evacuees, must be maintained by fire fighters during the evacuation process.

Resources. Personnel, vehicles, and equipment required to overcome the problems incidental to an aircraft accident/incident.

Response Time. The total period of time measured from the time of an alarm until the first

ARFF vehicle arrives at the scene of an aircraft accident and is in position to apply agent to any fire.

Restricted Articles. See Dangerous Goods.

Runoff. Liquids that flow by gravity away from an aircraft accident and might include aviation fuel (ignited or not), water from fire fighting streams, liquid cargo, or a combination of these liquids.

Runway. A defined rectangular area on a land airport prepared for the landing and taking off of aircraft along its length. Runways are normally numbered relative to their magnetic direction.

Salvage. A fire fighting procedure for protecting property from further loss following an aircraft accident or fire.

Self-Contained Breathing Apparatus (SCBA). A respirator worn by the user that supplies a respirable atmosphere that is either carried in or generated by the apparatus and is independent of the ambient environment.

Size-Up (Risk Assessment). A mental process of evaluating the influencing factors at an emergency prior to committing resources to a course of action.

Skin. The outer covering of an aircraft fuselage, wings, and empennage.

Smoke Ejector. A mechanical device, similar to a large fan, that can be used to force heat, smoke, and gases from a post-fire environment and draw in fresh air.

Surface Movement Guidance and Control System (SMGCS). A process or plan used by airports conducting operations in visibility conditions less than 1200 ft runway visual range (RVR).

Tabletop Training. A workshop style of training involving a realistic emergency scenario and requiring problem-solving participation by personnel responsible for management and support at emergencies.

Theoretical Critical Fire Area (TCA). The theoretical critical fire area (TCA) is a rectangle, the longitudinal dimension of which is the overall length of the aircraft, and the width includes the fuselage and extends beyond it by a predetermined set distance that is dependent on the overall width. Therefore, the aircraft length multiplied by the calculated width equals the size of the TCA.

Threshold. The beginning of that portion of the runway usable for landing.

Titanium. A lightweight, strong alloy with a high resistance to heat and fire. It is difficult to extinguish once ignited. Used mostly for engine parts and adjacent engine areas.

Triage. The sorting of casualties at an emergency according to the nature and severity of their injuries.

Triage Tag. A tag used in the classification of casualties according to the nature and severity of their injuries.

Turboprop Aircraft. An aircraft powered by one or more turbine engines each of which drives a propeller.

Turret. A vehicle-mounted master stream appliance.

Undercarriage. All components of an aircraft landing gear assembly.

United Kingdom Civil Aviation Authority (CAA). An agency charged with the responsibility of regulating safety in civil aviation.

Ventilation. The systematic removal of heated air, gases, and smoke from a fire area and replacing it with fresh air.

Vertical Stabilizer. That portion of the aircraft's empennage that contains the rudder.

Chapter 2 Pre-Incident Planning for Aircraft Emergencies

2-1 General.

2-1.1

Many accidents within the critical rescue and fire fighting access area involve undershoots, overshoots, and rejected takeoffs, and are generally survivable.

Accidents occurring outside of the critical rescue and fire fighting access area could involve impact with adverse terrain with resultant rupture of the aircraft structure.

Rapid response to these areas is crucial for the purpose of saving lives.

2-1.2

In addition to routine training programs, airport ARFF services and all structural fire departments and community emergency services with jurisdictions adjacent to an airport or its traffic patterns are encouraged to frequently schedule and participate in multi-agency training sessions based on the material in this guide. The objective of these sessions should be to focus on achieving maximum unity, compatibility, and effectiveness at aircraft emergencies should they be on or off the airport. (*See Section 2-5.*)

2-1.3

All airport and community emergency services should participate in annual exercises involving a simulated aircraft accident. Frequent command-level training for those persons assigned to major roles in the airport/community emergency plan is also essential. Command training can be presented in the form of workshop or tabletop exercises designed to develop effective emergency management techniques. Guidance for emergency plan exercises is provided in NFPA 424, *Guide for Airport/Community Emergency Planning*.

2-1.4

Command authority at any accident site should be predetermined according to the jurisdictional responsibilities of the agencies involved and as designated in their airport/community mutual aid agreement.

2-2 Emergency Response Preplanning.

2-2.1

All ARFF vehicles in use at the airport should be able to meet the provisions of NFPA 414, *Standard for Aircraft Rescue and Fire Fighting Vehicles*, upon acceptance from the manufacturer and should be maintained in a manner to ensure such levels of performance. Special training should be provided to enhance the skills of all vehicle operators, as their performance is critical to successful vehicle utilization, particularly under unfavorable conditions.

2-2.2

Operators assigned to each ARFF vehicle should make trial runs to all areas of the airport in all weather conditions during which flight operations take place. Particular emphasis should be placed on the ability to respond to the critical rescue and fire fighting access area since this is where most accidents occur. These runs will demonstrate each vehicle's operational capability and the time required to reach each site. Since many aircraft accidents occur in the overrun areas of the runways, it is important to provide suitable routes for use by the vehicles to enable them to reach these areas. Bridges spanning gullies, streams, ditches, cattle grids, or other ground surface appurtenances should be capable of supporting at least 120 percent of the weight of the heaviest emergency vehicle.

2-2.3

Where construction work of any kind is likely to affect the response capability or operational performance of the ARFF service, prior notification of the work should be provided so that amendments can be made to operational procedures to overcome or minimize their effect. This is particularly important where work on airport water mains is likely to close down one or more fire hydrants.

2-2.4

In order to provide multivehicle access to the accident site, service roads should be so constructed that one vehicle cannot block ingress or egress for other emergency vehicles. This can be accomplished by providing roads of sufficient width or suitable passing and turnaround areas.

2-2.5

Frangible gates or fence sections should be located at strategic locations to allow rapid access by ARFF vehicles to areas outside the airport boundary. Keys to gate locks should be carried on each authorized emergency vehicle, by airport security personnel and designated local emergency services.

2-2.6

Grid maps should be provided for each airport and its environs. They should be ruled with numbered and lettered grids (*see Figure 2-2.6*) to permit rapid identification of any response area. The area covered by a grid map should be a distance of 5 mi (8 km) from the center of the airport. This can vary depending upon the type of terrain or location of the airport in relation to other emergency facilities. Map nomenclature should be compatible with that used by off-airport public safety authorities. Two or more maps might be required where the area exceeds a 5-mi (8-km) radius. One map should display medical facilities, heliports, and other features according to the airport/community emergency plan. Where more than one grid map is used, grid identifications should differ by color and scale to assist in their identification. Prominent local features, access routes, staging areas, and compass headings should be shown to facilitate locating accident and medical facility sites. Copies of grid maps should be prominently displayed at Air Traffic Control, the airport operations office, each airport and community fire station, all mutual aid services, and carried on all appropriate emergency vehicles.

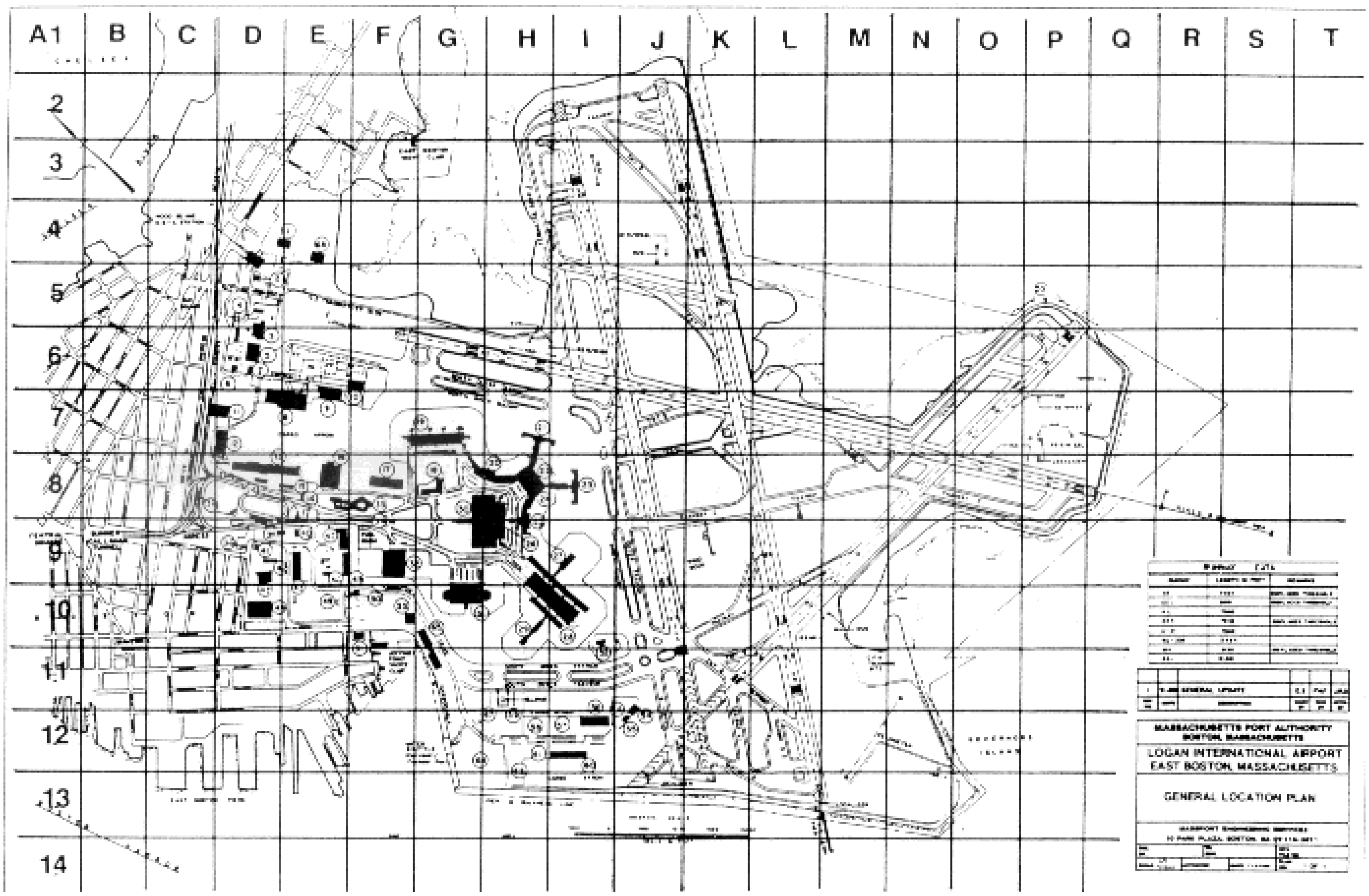


Figure 2-2.6 Typical airport grid map.

2-2.7

Backup systems should be provided in airport fire stations to allow for the rapid operation of vehicle bay doors, for the efficient reception/transmission of vital communications, and for the provision of emergency lighting.

2-2.8

A communication system from the airport to community or regional emergency services should be provided. The reliability of the system should be tested daily.

2-2.9

Any off-airport emergency services authorized to respond to an on-airport incident should pre-incident plan access to the various areas of the airport, particularly the designated staging areas. Personnel should also be trained in the special procedures to be followed once on the airport.

2-2.10

Sufficient ARFF vehicles and equipment should be provided to meet the required level of protection as specified in NFPA 403, *Standard for Aircraft Rescue and Fire Fighting Services at*

Airports, for the airport during flight operations. When this protection level is reduced for any reason (i.e., off-airport response, mechanical breakdown, lack of qualified personnel, etc.), all incoming and departing aircraft should be notified of the change in ARFF capability.

2-2.11

It is important that pre-incident planning includes response of additional pumping vehicles, ladder trucks, elevated platform vehicles, portable lighting equipment, hoisting and lifting equipment, medical supplies, and any other available specialized equipment or vehicle for which a requirement is anticipated. It is extremely important that the pre-incident plan also ensures the immediate availability of the special vehicles and equipment, provision for qualified driver-operators, and especially the availability of approving authority on an around-the-clock basis.

2-3 Airport Fire Fighter Basic Knowledge.

2-3.1

To assure that airport fire fighters have a suitable degree of skill, basic training should be provided in accordance with NFPA 1003, *Standard for Airport Fire Fighter Professional Qualifications*.

2-3.2

Comprehensive, continuous in-service training should be provided to maintain each fire fighter's proficiency. For further information on training subjects, see the references listed in Chapter 14 and Appendix F. The following are specific basic training requirements for ARFF personnel.

2-3.3

The complexity of modern aircraft and the variety of types in service make it difficult to train ARFF personnel in all the important design features of each model. However, they should become as familiar as possible with each type of aircraft that normally uses the airport. Particular emphasis should be placed on the following (*see also NFPA Aircraft Familiarization Charts Manual*):

(a) Location and operation of normal and emergency exits, cargo doors, equipment, and galley access doors;

(b) Seating configurations;

(c) Type of fuel and location of fuel tanks;

(d) Location of ejection seats and armament (military aircraft);

(e) Locations of batteries, hydraulic, and oxygen systems;

(f) Positions of break-in points on the aircraft;

(g) Location of rapidly activated standby generators or turbines;

(h) Fire access panels; and

(i) Location of aircraft construction materials that are subject to be releasing hazardous/toxic substances while burning (i.e., carbon fibers, etc.).

2-3.4

Airports are large commercial complexes that contain many potential life and fire hazards. These hazards vary relative to aircraft operations, time of day, weather conditions, construction, or a combination of these factors. It is, therefore, vital that ARFF personnel become extensively knowledgeable about the airport and any changes that occur that could adversely affect immediate response or the efficient performance of their rescue and fire fighting responsibilities. Minimum requirements of knowledge should include:

(a) Water supply locations (hydrants);

(b) Runway identifications and locations;

(c) Taxiway identifications and locations;

(d) Airport lighting systems;

(e) Most effective response routes and alternatives;

(f) Fuel handling and storage areas;

(g) Key airport locations;

(h) Airport service roads;

(i) Gates and fences; and

(j) Airport drainage systems.

2-4 Communications.

2-4.1

All airport emergency vehicles should be provided with multiple channel two-way radios operating on the airport's assigned ground control frequency and other airport emergency frequencies.

2-4.2

It is desirable that airport ARFF vehicles be able to monitor or be in direct voice communications with an aircraft during an emergency situation. This procedure is especially important when airport control towers are not in operation.

2-4.3

At an aircraft accident site, power megaphones can be valuable tools to coordinate flight deck crew/ARFF activities, direct evacuating aircraft occupants to safe locations, etc.

2-4.4

Portable radios can be utilized at an accident site to communicate with the command post, airport emergency dispatcher, airport management, arriving back-up units, etc. Where personnel and vehicles from more than one agency will operate in mutual support, common radio frequencies should be available. If not, pre-incident planning procedures should be established so that portable radios can be exchanged, the use of messengers employed, or methods of relaying messages through the command post utilized. When portable radios are exchanged, consideration should be given to avoiding channel saturation and the maintenance of communication discipline.

2-4.5

Experience from recent accidents has shown that the use of automated voice notification systems greatly facilitates emergency response/mutual aid notification.

2-4.6

The use of cellular telephones in ambulances, in supervisory vehicles, and in command post vehicles can provide significant benefits in command and control functions.

2-5 Mutual Aid Considerations.

2-5.1

As indicated previously, it is essential to have mutual fire fighting assistance agreements with community and regional, off-airport fire departments. Successful rescue operations and handling of aircraft accident fires both on and off the airport depends on pre-incident planning the effective use of mutual aid (*see also Appendix E*). The following considerations are significant:

(a) Special attention should be given to ensuring compatibility in equipment designs (i.e., fire hose threads, communications equipment, etc.) and to fire control operational techniques.

(b) It is important to familiarize structural fire department personnel with the special problems relating to aircraft rescue and fire fighting including methods of access to aircraft operating areas and how to operate vehicles while on the airport.

2-5.2

Airport orientation visits should be arranged by fire departments bordering airports for consultations with the airport fire department, airlines, the military services, and others as appropriate. Their training in airport/aircraft familiarization should include those items listed in 2-3.3 and 2-3.4, diagrams in the NFPA *Aircraft Familiarization Charts Manual*, and grid maps of the airport and surrounding area.

2-5.3

Structural fire fighting vehicles normally carry small amounts of water as compared to the amounts usually carried on major airport ARFF vehicles. However, they can be useful in relaying water from hydrants, reservoirs, or other sources to maintain ARFF vehicle supplies.

2-5.4

Structural fire fighters can be utilized to provide assistance to airport ARFF personnel by handling hose lines, operating tools and equipment, assisting in rescue operations, and protecting exposures.

Chapter 3 Flight Deck Crew and ARFF Personnel Responsibilities

3-1 Areas of Responsibility.

3-1.1

The flight deck crew, flight attendants, and ARFF personnel should have the skills to deal with aircraft emergencies and should be familiar with each others' responsibilities to ensure that all their efforts are clearly directed toward the common goals of life and fire safety.

3-1.2

The prime mission of all concerned is the safety of all persons aboard the aircraft and any others involved in the emergency. Duties and responsibilities can generally be defined as follows:

(a) Flight deck crews hold the primary responsibility for the aircraft and for the safety of its occupants. The final decision to evacuate an aircraft and the manner in which the evacuation is carried out are made by the flight deck crew provided they are able to function in the normal manner at the time.

(b) Flight deck crews and flight attendants share responsibility for the aircraft and for the safety of its occupants. The final decision to evacuate an aircraft and the manner in which the evacuation is carried out are made by the flight deck crews and flight attendants provided they are able to function in the normal manner at the time.

(c) It is the duty of responding ARFF personnel to create conditions in which survival is possible and evacuation or rescue can be conducted. As visibility from within an aircraft is limited, any external features or situations likely to be of significance in the evacuation process should be communicated to the aircraft's crew. Should it become apparent that the crew's incapacity precludes the initiation of evacuation, the officer in charge of the ARFF personnel should take the initiative.

3-1.3

To prevent injury when an emergency aircraft evacuation takes place, consideration should be given to assist occupants using the aircraft slides.

3-2 Communications.

3-2.1

Effective communications between flight deck crew and ARFF personnel is very important during emergencies. Contact should be established at the earliest possible time between persons in charge of each group. Exchange of pertinent information can assist in developing better decisions and plans of action. Several methods of direct communication are generally available such as aircraft interphone, tower relay, direct radio communication via approved frequency or visual signals.

3-2.2

Where aircraft engines are operating, radio communications near the aircraft can be very difficult. Most aircraft are equipped with intercom systems and provided with plug-in jacks normally located under the forward portion of the aircraft near the nose gear. ARFF personnel should be aware of this means of communication and carry the necessary headset and microphone to plug into these facilities. Even with the engines operating, direct communications with the flight deck crew can be established by use of this system as long as the power is on.

3-2.3

Where a more direct means of communication cannot be established, the officer in charge of the responding ARFF personnel should go to the left side of the aircraft nose and establish direct eye contact and voice communications with the captain of the flight deck crew. If engine noise is a problem and a power megaphone is not available, it might be necessary to resort to hand signals to communicate. Figure 3-2.3 depicts standard international ground to aircraft hand signals that should be used by ARFF personnel to communicate with the captain during emergencies.

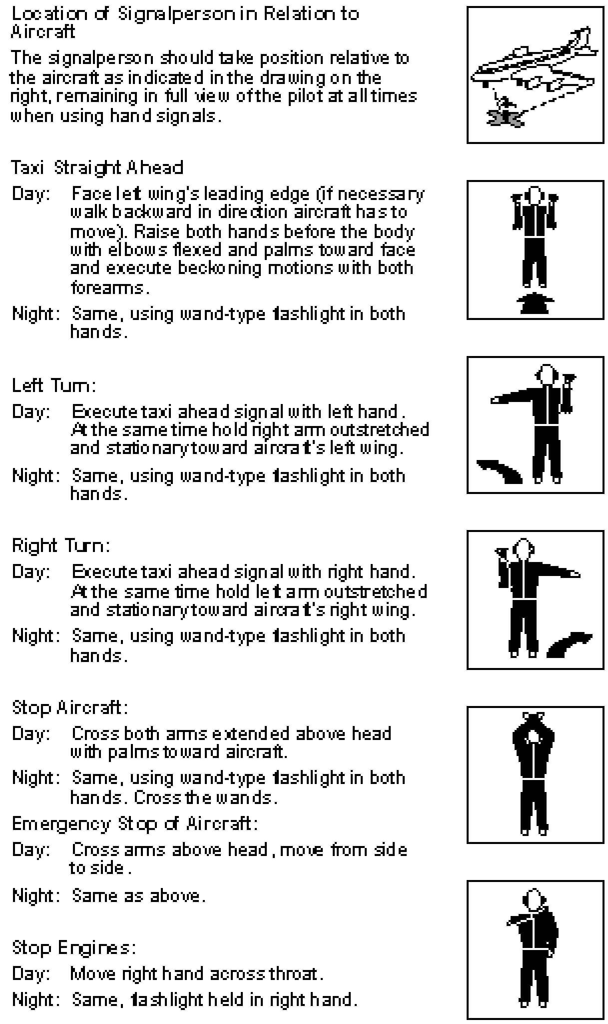


Figure 3-2.3 Standard international ground to aircraft signals.

3-2.4

If aircraft engines are operating, ARFF personnel should use extreme caution when approaching an aircraft for communications purposes as described in 3-2.2 and 3-2.3. The aircraft should be approached only from the front and well ahead of the nose and, if possible, in full view of the captain. Vehicle and hand-held lights should be used in periods of darkness and poor visibility.

Chapter 4 Emergency Response

4-1 General.

4-1.1

The survivable atmosphere inside an aircraft fuselage involved in an exterior fuel fire is limited to approximately 3 minutes if the integrity of the airframe is maintained during the impact. This time is substantially reduced if the fuselage is fractured. When the aluminum skin is directly exposed to flame, burnthrough will occur within 60 seconds or less while the windows and insulation may withstand penetration for up to 3 minutes. Because of this serious life hazard to occupants, rapid fire control is critical. Therefore, whenever flight operations are in progress, ARFF vehicles and personnel should be so located that optimum response and fire control can be achieved within this time frame.

4-1.2

At many airports portions of the critical rescue and fire fighting access areas might be outside the airport boundaries. There also can be obstructions created by natural features, highways, or railroad right-of-ways that would delay or preclude access by ARFF vehicles. Consideration should be given in these instances to providing specialized vehicles where conventional vehicles can be restricted due to unusual terrain characteristics. Any delay in response time is critical, and mutual assistance agreements with off-airport agencies should be established to provide optimum response in problem areas. (*See Figure 4-1.2*.)

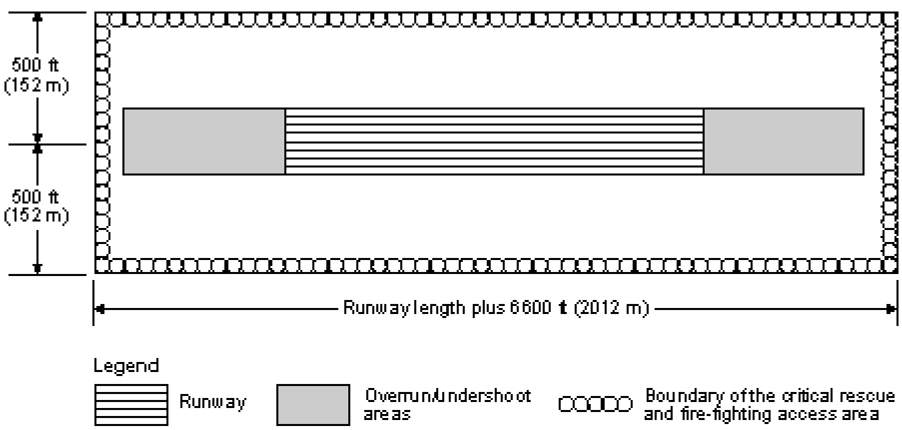


Figure 4-1.2 Critical rescue and fire fighting access area.

4-1.3

To obtain the desired response, pre-incident planning should include a wide range of factors such as adequate alarm systems, fire station locations (or prepositioning of resources), vehicle operator training, and airport familiarization.

4-1.4

Fire stations should be located so that rapid direct access to the operational runway utilizing maximum acceleration rate and top speed of the vehicles is utilized to enable them to reach any point on the runway. The access road to the runway should be as direct as possible.

4-1.5

All-weather access routes to the critical rescue and fire fighting access area suitable for ARFF vehicles should be designated and should be maintained in usable condition while flight operations are in progress.

4-1.6

To minimize response times, operational procedures should exist through which Air Traffic Control (ATC) would stop or divert all aircraft and nonessential traffic that would conflict with responding emergency vehicles.

4-1.7

Airports updating their master plan for airport development should consider obstruction clearance in the critical rescue and fire fighting access area such as ditches, mounds, or vegetation that would cause extensive damage to any overrunning aircraft or obstruct the positioning of the emergency vehicles. Boat launching ramps should be considered in those areas that terminate at large bodies of water.

4-2 Low Visibility Operations.

4-2.1

New and improved techniques for instrument takeoff and landing permit flight operations to continue under adverse weather conditions. Low visibility operations criteria vary from one airport to another depending upon the type of instrument landing system available, the level of natural and manmade obstructions in the surrounding terrain, the type of runway lighting, and the capability of the onboard instrument systems of the aircraft using the airport. Such operational minimums can vary from 3 mi (5 km) visibility to 300 ft (100 m) for landings and with similar restrictions for takeoff. ARFF personnel should ascertain operational restriction levels from the local Air Traffic Control (ATC) agency in order to establish response capability under minimum visibility conditions.

4-2.2

Although aircraft operational navigational weather minimums might not be in effect, fully staffed Alert 1 standby procedures should be initiated when flight operations are in progress and surface visibility and conditions are less than $^1/_2$ mi (800 m). (*See also Section 8-2*.)

4-2.3

Standbys during low visibility operations and adverse weather conditions should have at least one major ARFF vehicle located at a distance no closer than the taxiway hold line adjacent to the midpoint of the active runway unless the fire station(s) location(s) permits effective response times. (*See Figure 4-2.3*.) When on standby, vehicle operators should keep engines running and all emergency lights operating. If the vehicle is equipped with a FLIR system, it should be fully operational with an in-cab display.

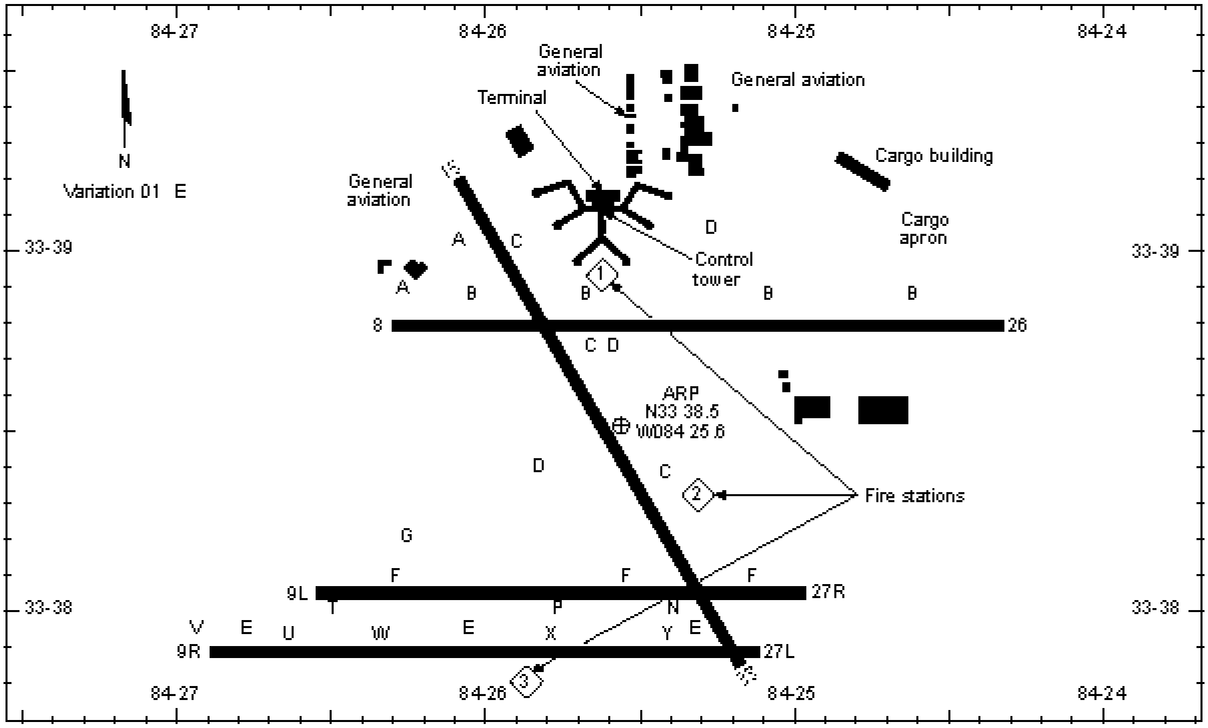


Figure 4-2.3 Example of airport fire station locations.

4-2.4

ARFF personnel assigned to any standby should monitor all applicable radio frequencies.

4-2.5

Air Traffic Control (ATC) should be made aware of the exact location of the ARFF vehicles assigned to standby duty. Where available, surface navigational aids, such as ground radar (ASDE), should be fully utilized through coordination between ARFF personnel and the control tower.

4-2.6

ARFF vehicles can be equipped with an infrared vision system to assist the crew of the vehicles to locate and respond to emergencies in low visibility conditions.

4-2.7

Positioning equipment can be installed on ARFF vehicles to enable the drivers to know their position on the airport at all times.

4-3 Considerations for Airports Adjacent to Water.

4-3.1

Where airports are situated adjacent to large bodies of water such as rivers or lakes, or where they are located on coastlines, special provisions should be made to expedite rescue.

Injured survivors and nonswimmers can drown in water in the same length of time that it takes to die in a fire.

4-3.2

Inclined ramps or docking facilities should be considered by airports located adjacent to large bodies of water to allow rapid response to aircraft accidents. Launch ramps should be located in the overrun areas of the critical rescue and fire fighting area.

4-3.3

For rescue purposes, the vessel should be equipped with flotation platforms and/or life rafts for the maximum number of occupants carried on the largest aircraft regularly scheduled into the airport.

4-3.4

Rescue vessels should be capable of rapid response to the critical rescue and fire fighting area.

Chapter 5 Factors Common to Airport Emergencies

5-1 General.

5-1.1

The primary hazard associated with aircraft accidents is that liquid fuels are likely to be released and ignited during the accident sequence. A secondary hazard is that fuels released but not ignited could subsequently be ignited prior to or during the egress of occupants. In addition, fires involving combustible materials such as interior furnishings, stored goods, and electrical system components can occur. Further complications could result if the aircraft comes to rest in such an attitude that forcible fuselage entry might be required.

5-1.2

During all aircraft emergencies, all persons not directly involved in the ARFF phase of the incident, including the news media, should be required to stay well clear of the site until evacuation, occupant care, full fire control, and site safety security are completed. Responsibility for site security should be preassigned to the airport police and could be augmented by local police, guards, and volunteers as needed.

5-2 Types of Emergency Alerts.

5-2.1

The terms used to describe categories of emergency alerts are not standardized. The Federal Aviation Administration (FAA) terms, Alert I, Alert II, and Alert III, and the International Civil Aviation Organization (ICAO) terms, “Local Standby,” “Full Emergency,” and “Aircraft Accident,” are equivalent. Individual airports might have adopted their own nomenclature for alerts 1, 2, or 3. This must be coordinated with the appropriate authority.

5-2.2 Alert I “Local Standby.”

When an aircraft has, or is suspected to have, an operational defect, the incident should be considered an Alert I. The defect should not normally cause serious difficulty for the aircraft to achieve a safe landing.

5-2.2.1 Under Alert I conditions, at least one ARFF vehicle should be staffed and positioned to permit immediate use in the event of an accident. If the time and conditions permit, ARFF personnel should be advised of the (1) aircraft type, (2) number of passengers and crew, (3) amount of fuel remaining, (4) nature of the emergency, (5) type, amount, and location of dangerous goods aboard, and (6) number and location of nonambulatory passengers onboard, if any. All other in-service ARFF vehicles should remain available for immediate response.

5-2.2.2 An Alert I should also be initiated when an aeromedical evacuation aircraft with patients aboard is approaching or departing the airport.

5-2.2.3 Alert I procedures should be implemented whenever required response times cannot be achieved. Factors that can affect response times include construction work, field maintenance, adverse weather conditions, and low visibility. (*See Chapter 2 and Chapter 4.*)

5-2.2.4 Airports should have management policies for implementation of Alert I procedures during arrival and departure of certain categories of aircraft that do not normally use the airport.

5-2.3 Alert II "Full Emergency."

When an aircraft has, or is suspected to have, an operational defect that affects normal flight operations to the extent that there is danger of an accident, the incident should be considered to be an Alert II, "Full Emergency."

5-2.3.1 When an Alert II emergency is declared, ARFF personnel should be provided with detailed information that allows preparation for likely contingencies. A full response should be made with the ARFF vehicles staffed and in position with engines running and all emergency lights operating so that the fastest response to the accident/incident site can be accomplished.

5-2.3.2 It is important that appropriate radio frequencies be continuously monitored by ARFF personnel. One or more major ARFF vehicles should be able to initiate fire suppression within the briefest period of time after the aircraft comes to rest. Standard standby positions for ARFF vehicles should be established for a variety of anticipated circumstances.

5-2.3.3 ARFF personnel should be informed of any changes in a distressed aircraft's emergency situation that could affect its touchdown point or ultimate behavior after touchdown.

5-2.4 Alert III "Aircraft Accident."

This alert denotes that an aircraft accident has occurred on, or in the vicinity of, the airport.

5-2.4.1 Regardless of the source of an Alert III alarm, full ARFF response should be put into effect. When possible, all known pertinent information should be relayed via radio by Air Traffic Control (ATC) to responding units and include, as accurately as possible, the accident location using landmarks and grid map coordinates.

5-2.4.2 When an accurate accident location is not available, ARFF personnel should anticipate the worst situation and stand by until signs of an accident are evident or better information is given. Mutual aid assistance should be initiated in accordance with the airport/community emergency plan. (*See also NFPA 424, Guide for Airport/Community Emergency Planning, and ICAO Airport Services Manual, Part 7.*)

5-3 Vehicle Response to Aircraft Accidents.

5-3.1

ARFF vehicles should approach any aircraft accident by the route that provides the quickest response time. This might not necessarily be the shortest distance to the scene. Traversing through unimproved areas can take longer than traveling a greater distance on paved surfaces such as taxiways, ramps, and roads. Total response time is vital. Preferred routes, especially those within the critical rescue and fire fighting access area, should be preselected. Practice response runs should be made under both ideal and inclement weather conditions.

5-3.2

In some cases, runways and taxiways are blocked by aircraft awaiting taxi clearance or takeoff. Vehicle operators should be aware of alternate routes that can be used so as not to delay response.

5-3.3

The load-bearing characteristics of the airport soil structure under various weather conditions should be known, and vehicle operators should be trained to deal with off-road driving conditions.

5-3.4

When nearing the accident scene, vehicle operators should be alert to avoid all persons in the area, especially those who might be injured, unconscious, or wandering about in a dazed condition. In darkness, periods of low visibility, or when operating in areas of tall vegetation, extra caution and effective use of spotlights, floodlights, portable lighting, audible warnings, or FLIR systems (if provided) are required.

5-4 Positioning of ARFF Vehicles.

5-4.1

Information from the flight deck crew relative to the nature of the emergency will assist the ARFF personnel to better determine the most advantageous positioning of the vehicles upon arrival at the scene of an aircraft emergency.

5-4.2

Piston-type engine aircraft provide more options for initial positioning of ARFF vehicles than do turbojet aircraft that have swept-back wings and produce a jet blast hazard. ARFF personnel should therefore consider an approach from the nose of jet aircraft. However, this should not become a standard procedure as wind conditions, terrain, type of aircraft, location of engines, cabin configurations, and other factors can dictate the optimum approach in a given circumstance.

5-4.3

Vehicle position should never obstruct aircraft evacuation or interfere with the deployment of evacuation slides. (*See also Chapter 7*.)

5-4.4

Propellers turning on turboprop or piston-type engine aircraft present a hazard to evacuees and ARFF personnel. Turbojet engines present different problems. For example, the areas directly ahead of and for a considerable distance behind the engines should be avoided because of the intake and jet blast hazards. Turbojet engines will rotate for a considerable time after they have been shut down. (*See Figure 5-5.6*.)

5-4.5

When combination cargo/passenger (COMBI) aircraft have declared an emergency, ARFF personnel should be informed of cabin configurations prior to the landing. Since some cargo areas extend over the wings, the overwing exits could be unavailable for use as emergency exits.

5-4.6

The mission of the first-arriving ARFF vehicle and crew is to assist in evacuation of occupants, prevent the outbreak or spread of fire, and perform any rescue operations required. The vehicle should be positioned to protect the principal evacuation route being used by the occupants. When it is obvious that the occupants are evacuating safely without assistance and the fire or threat of fire is controlled, later-arriving vehicles and crews can be strategically positioned and tasks assigned. Caution must be exercised to avoid placing evacuees, ARFF personnel, or vehicles in locations that could become hazardous in the event of a sudden extension of fire.

5-5 Hazards to ARFF Personnel.

5-5.1

ARFF personnel should always remain alert to the possibility of ignition of flammable vapors that are always present in the area of damaged aircraft. Elimination of ignition sources and the maintenance of an unbroken foam blanket is the best procedure in preventing ignition of these vapors.

5-5.2

All ARFF personnel should be provided with and be required to wear proper and complete protective clothing and equipment. Minimum protective clothing and equipment as approved by the authority having jurisdiction. Personnel should be fully trained in the use limitations and value of such protective clothing and equipment by utilizing them in frequent fire fighting drills.

5-5.3

Aircraft structures damaged by fire or impact forces are often very unstable and subject to collapse or rollover. If these conditions are suspected to exist, precautions in the form of blocking or shoring should take place as soon as practicable to ensure the safety of ARFF personnel working in the area. Blocking and shoring nonessential to rescue and fire fighting operations should not be undertaken by ARFF personnel.

5-5.4

If dangerous goods are believed to be involved in an emergency, procedures should be carried out as prescribed in the U.S. Department of Transportation *Emergency Response Guidebook*. This also includes incidents involving agricultural spraying aircraft and the associated pesticides.

5-5.5

Any undercarriage fire creates a potential for aircraft collapse or the explosive disintegration of affected components.

5-5.6

ARFF personnel should stay well clear of an operating jet engine to avoid intake and exhaust hazards. (*See Figure 5-5.6.*)

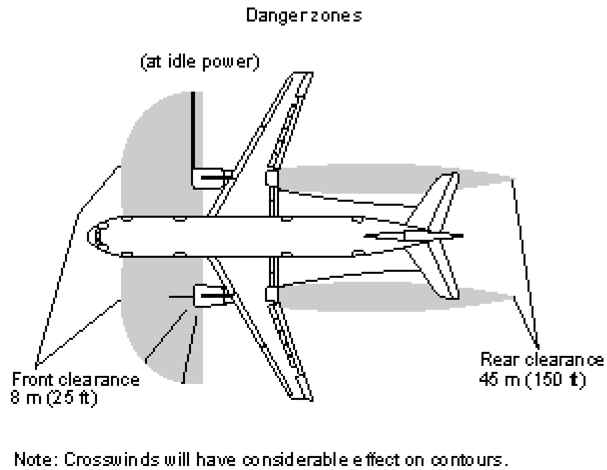


Figure 5-5.6 Engine run danger areas.

5-5.7

The propellers of piston-type engine aircraft should never be moved when at rest, as any movement could, under certain conditions, restart the engine.

5-5.8

Some modern jet aircraft are equipped with Ram Air Turbines (RAT) or Air Driven Generators (ADG) designed to provide back-up electrical and hydraulic power in the event of in-flight failures of primary systems. These devices are often designed to deploy from flush fuselage or engine-mounted storages, and some can deploy with considerable force. ARFF personnel should become aware of aircraft employing these systems and their locations. Serious injury could result should the RAT accidentally deploy and strike a person during emergency operations. (*See Figure 5-5.8.*)

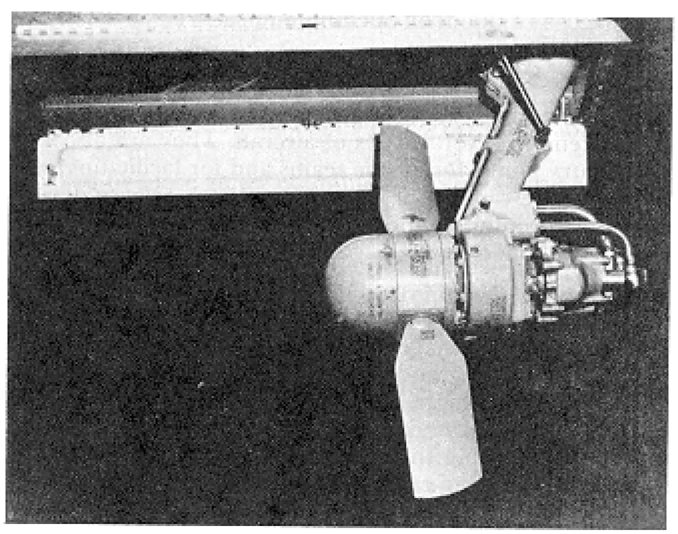


Figure 5-5.8 Ram Air Turbine. Shown is a deployed Ram Air Turbine on a Lockheed 1011 aircraft. It is located at the center underside of the fuselage slightly forward of a point directly in line with the main landing

gears.

5-5.9

On Boeing 767, if the ground spoilers are deployed and an overwing plug is opened, they will rapidly retract down. This is done so that exiting passengers will not be hampered in evacuation. The slide also deploys from the side of the fuselage.

Chapter 6 Aircraft Construction and Materials

6-1 Construction Materials.

6-1.1

ARFF personnel should become familiar with aircraft construction materials. Most of these materials have a low resistance to flame exposure, and their behavior under fire conditions should be understood. They have high resistance to cutting or other forcible entry methods that can sometimes be difficult and time consuming and can virtually impede successful rescue and fire fighting operations.

6-1.2

Much of a modern aircraft structure is aluminum alloy. It is approximately 50 percent lighter than steel, and its normal appearance is light gray or a silvery surface when polished. It is used as sheets for aircraft skin surfaces, as channels for framework, and as plates and castings for bulkheads and fittings. This metal will not contribute to a fire to any significant degree. However, it will melt under the high temperature conditions found in aircraft fires. For this reason it is essential to keep fuselage surfaces cool during rescue operations.

6-1.3

Magnesium alloys are used for wheels, engine mounts, brackets, crankcase sections, cover plates, and other engine parts. The appearance of this metal is silvery-white or grayish, and it is about two-thirds the weight of aluminum. While it is not easily ignited, when it is ignited it burns violently and cannot be easily extinguished. It thus presents a serious reignition source. Sparks developed when the metal comes in contact with paved surfaces, as might occur in a wheels-up landing, have the capability of igniting flammable vapors.

6-1.3.1 Where special extinguishing agents are not available for magnesium fires, water in coarse heavy streams might provide a suitable alternative fire control method. At first, such streams will result in localized intensification of flame and considerable sparking and showering of burning magnesium. Isolated burning pieces of magnesium should be removed from flammable vapor areas.

6-1.4

Steel in various forms, including stainless steel, is used in aircraft engine parts, around engine nacelles, engine fire walls, flap gear, and tubing. The metal presents no fire hazard, nor does it contribute to a fire except that it can create friction sparks when in contact with hard surfaces during a wheels-up landing. The sparks have sufficient energy to ignite flammable vapors. In most forms used in aircraft, steel can be cut with metal cutting saws, but because of the sparks produced, it is a potentially hazardous operation in the presence of flammable vapors.

6-1.5

Titanium is used primarily in engine parts, nacelles, and for engine fire walls. It is a combustible metal but in the forms used in aircraft, it has a high degree of heat and fire resistance. Once ignited, titanium is difficult to extinguish. Water is ineffective. Turbine engine fires involving titanium cannot normally be extinguished by external fire fighting techniques within the time period necessary to complete rescue operations. Titanium metals are a friction spark hazard similar to steel and magnesium. Surfaces of titanium are very difficult to penetrate, even with power equipment.

6-1.6

To improve the payload/vehicle-weight ratio of aircraft without compromising structural strength, increasing use is being made of composite materials. They are made of small, fine fibers embedded in carbon/epoxy materials. The fibers are usually boron, fiberglass, aramid, or carbon in the form of graphite. Composite, fiber-plus-plastic materials have replaced metal in many aircraft components. These materials do not present any unusual fire extinguishment problems.

6-1.7

Many aircraft cabin materials in current and continuing use as well as newer fire-resistive materials can produce high concentrations of toxic gases when heated even though no open flaming is visible. Therefore, it is imperative that positive pressure self-contained breathing apparatus be worn by all fire fighters engaged in rescue, fire fighting, and overhauling operations.

6-2 Aircraft Fuel Tanks.

6-2.1

In some aircraft, where the wing joins the fuselage, there is no substantial separation to provide a desired fire wall. As all aircraft have wing tanks, many without separate metal or synthetic bladders within the wing cavity, vapors are seriously exposed under fire conditions.

6-2.2

Some aircraft carry fuel in the center wing section, which in effect places fuel storage within the fuselage. It is thus possible, under some conditions, for fuel or vapors from tanks damaged due to an aircraft accident to enter the fuselage.

6-2.3

Currently entering commercial service are wide-body aircraft with provisions for additional fuel storage within both the horizontal and vertical stabilizers. Damage to these tanks in the event of an aircraft accident poses a number of problems including those where fuel or vapors might enter occupied sections of the aircraft and become ignited. These additional fuel storage locations can complicate the fire fighting operations and will require additional agent. (*See also NFPA 403, Standard for Aircraft Rescue and Fire Fighting Services at Airports*.)

6-2.4

Wing tanks on some aircraft are located directly above or to the side of landing gear mounts. These tanks have been ruptured during hard landings or other ground accidents.

6-3 Aircraft Exits.

6-3.1

Aircraft exits on transport category aircraft include doors, hatches, and windows of various sizes. These exits will vary with the age, size, and types of the aircraft. ARFF personnel should be familiar with the operation of the various exit types on all makes of aircraft normally using the airport.

6-3.2

Doors on most older, unpressurized aircraft open outward and can be opened from outside and inside the aircraft.

6-3.3

The doors on the majority of U.S. built modern pressurized aircraft are called "plug-type" doors. When these doors open, they push in slightly and then pull out or retract upward into the ceiling. These doors are not operable as long as the cabin remains pressurized [as little as 0.015 psi (103 Pa)].

6-3.4

Aircraft having a door sill higher than 5 ft, with landing gear deployed, are normally equipped with inflatable evacuation slides mounted at the emergency exits. When the system is armed and the emergency exit is opened, the slide can inflate and extend outward in less than 5 seconds with considerable force. ARFF personnel therefore should consult aircraft manufacturer crash charts to be knowledgeable of the areas where those inflatable slides deploy. (*See NFPA Aircraft Familiarization Charts Manual*.)

6-3.5

Doors should be approached and opened with caution, as the slide might deploy either by design or malfunction.

6-3.6

When positioning ladders, elevated platforms, or mobile stairways prior to opening cabin doors from the outside, care should be taken since all aircraft doors do not open in the same direction, or by the same mode of operation.

6-3.7

Opening the doors of most modern-type aircraft from the exterior can be accomplished more readily and safely using an aerial platform or a mobile stairway. If these units are not available, a ground ladder can be raised to a position adjacent to the door control mechanism and, if possible, on the side away from the direction the door is to be opened. Once the door is opened the ladder can then be moved into the door opening and secured at the top to prevent movement.

6-3.8

Overwing exits are part of the emergency evacuation system on several types of aircraft. They might also be useful as entry points for rescue teams and for facilitating ventilation of the cabin. Some overwing exits are equipped with slides that are similar to door exit slides when deployed.

6-3.9

Some aircraft have doors that incorporate stairs on the side of the fuselage or in the tail section to facilitate passenger boarding and deplaning. Although in some circumstances they might be used as such, they are not considered emergency exits. ARFF personnel should know which aircraft using the airport have these types of doors and exercise proper caution when the need arises to open them.

Chapter 7 Evacuation and Rescue

7-1 Aircraft Evacuation.

7-1.1

Evacuation of occupants involved in aircraft accidents and assistance to those who cannot remove themselves should proceed with the greatest possible speed. While care is necessary in the movement of injured occupants so that their injuries are not aggravated, removal from the fire-threatened area is the primary objective.

7-1.2

Flight deck crews receive extensive training in aircraft emergency evacuation procedures. They are in the best position to make optimum decisions relative to evacuation procedures in most emergency situations. They also have immediate contact with those aboard the aircraft and therefore can direct the operations.

7-1.3

Prior to any planned emergency landing, flight deck crews normally will consider passenger relocation within the cabin. This procedure is used to expedite use of potential emergency exits. The practice of placing a crew member, or a person knowledgeable in evacuation procedures, at each exit to assist flight attendants in the direction and movement of occupants is common practice where time and circumstances permit.

Under certain circumstances, flight attendants might have the necessary time prior to impact to more fully instruct passengers on how to survive impact and evacuate the aircraft. Training and check lists provide, among other things, for selection of able-bodied helper passengers to receive instructions pertaining to operation of exits and slides. These persons would then be more capable of assisting the flight attendants. Additionally, ARFF personnel should realize that the first passengers to leave the plane might have received instructions to remain at the bottom of a slide, wing, airstair, etc. ARFF personnel should direct survivors away from the aircraft, and prevent survivors from piling up.

7-1.4

The tendency toward forward exiting is natural since most passengers boarded the aircraft at terminals through forward doors and will instinctively attempt to exit in the same manner. Other exit facilities are apt to be bypassed, especially if persons are under any mental strain or sense of panic. Overwing and other emergency exits requiring physical agility probably will be shunned by those doubting their ability to use them effectively. Access to overwing and some other emergency exits is usually restricted by seating arrangements. Overwing exits are often smaller than door exits, and have caused passengers to become entangled just inside the exit. If visibility in the cabin is impaired due to darkness or dense smoke, orderly evacuation can be further complicated.

7-1.5

Limited evacuation options might be available to the flight deck crew due to circumstances aboard the aircraft. One or more emergency exits could be inoperable as the result of distortion caused by impact. Doors might be blocked by loose galley equipment. Aisles might be difficult to travel due to injured passengers, collapse of overhead panels and partitions, dislodged seats, and carry-on items. Although normal evacuation procedures provide for the use of all available exits, flight deck crews are trained to remain flexible and are prepared to select the best means of exit as circumstances and conditions permit.

7-1.6

Many variations of aircraft accidents are possible, and the flight deck crew can be faced with many decisions in the seconds before or after they occur. ARFF personnel therefore cannot expect that standard procedures will be used in all instances and should remain flexible to provide whatever protection and support evacuees should require. In the event that the flight deck crew becomes incapacitated and evacuation does not begin immediately, ARFF personnel should initiate evacuation procedures.

7-1.7

If fire conditions or fuel spills initially prohibit the use of certain emergency exits, ARFF personnel are usually in a better position to make this observation. The ARFF officer in charge should not hesitate to communicate this information to the flight deck crew.

7-2 Evacuation Slides.

7-2.1

Evacuation slides are provided to expedite occupant egress from aircraft that have normal door sill heights above 5 ft. Because passengers are not trained in proper evacuation slide use, there is a degree of personal injury risk when slides are used. ARFF personnel should expect the occurrence of sprains, bruises, friction burns, and other minor injuries whenever evacuation slides are used. (*See Figure 7-2.1*.)

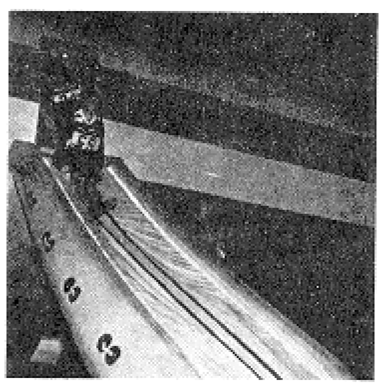


Figure 7-2.1 Photo shows proper entry and use of an evacuation slide.

7-2.2

If, during landing, the nose gear fails, the aircraft might come to rest in a tail-high attitude. The failure of one or more landing gears can result in a nose-high or listing attitude. In these instances, evacuation slides become somewhat ineffective because they do not deploy at the proper angle to the ground. A high percentage of injuries can be expected when evacuation slides are used under these circumstances. ARFF personnel should be able to reduce the amount and severity of injuries and expedite evacuation by manipulating the slides and assisting evacuees. (*See Figure 7-2.2*.)

Figure 7-2.2 Assisting evacuees at the base of an evacuation slide.

7-2.3

Aircraft evacuation slides are susceptible to heat and fire exposure. They are combustible, and when exposed to radiant heat they melt, then deflate, rendering them unusable. ARFF personnel should protect evacuation slides from heat and flame to the best of their ability but should be extremely careful not to apply foam to the operational area of the slide. Foam on the slide makes it very slippery and increases the descent speed of evacuees, possibly causing severe injuries. (*See Figure 7-2.3*.)

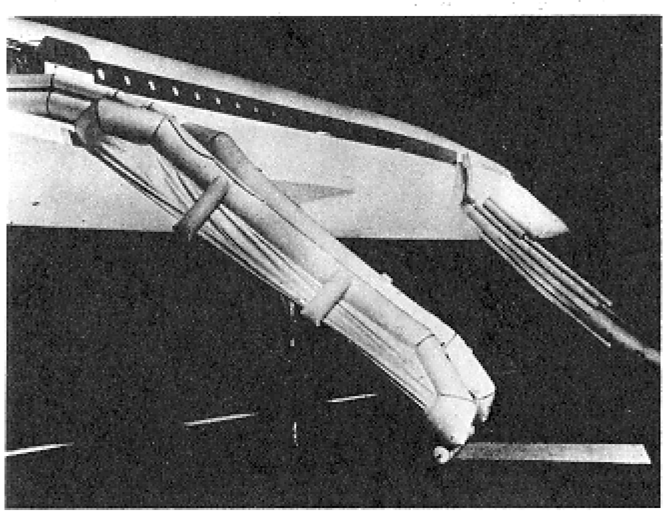


Figure 7-2.3 Photo shows two deployed evacuation slides. Evacuation slides are susceptible to heat and fire exposure.

7-2.4

If time and conditions permit, mobile stairways should be used as an alternative to deploying evacuation slides. This method of evacuation, when there is no immediate danger to aircraft occupants, would prevent many injuries. Response of available mobile stairways should be prearranged between ARFF personnel and one or more of the following:

(a) Airlines;

(b) Airport maintenance facilities;

(c) Airport operations.

7-3 Evacuation Assistance by ARFF Personnel.

7-3.1

The need to assist in aircraft occupant evacuation depends on a variety of factors. When occupants are self-evacuating, ARFF personnel should support the operation and expedite it where possible. In other instances, actions would depend on the degree of occupant survivability, the fire situation, the condition of exits, and the status of evacuation facilities. In any event, rescue efforts should begin with fire prevention/control and should maintain a safe path from egress points. Evacuees should be directed to an upwind location.

7-3.2

Fire prevention/control during evacuation should require strategic positioning of ARFF vehicles and applying foam from turrets to establish a blanket covering the Practical Critical Fire Area (PCA). During this operation, emphasis should be placed on maintaining safe egress paths and eliminating the threat of fire extension into the fuselage. Foam handlines, which are more maneuverable than turret streams, should then be employed to protect evacuees and ARFF personnel, extinguish spot fires, and maintain the integrity of the foam blanket. (*See also Chapter 5*.)

7-3.3

If time and conditions permit, ARFF personnel should assist in the off-loading of evacuees at the base of the evacuation slides to minimize injuries. When high winds or unusual aircraft attitudes cause slides to invert or malposition, an attempt should be made to align them manually.

7-3.4

Ground ladders might be needed to assist occupants who have exited onto wing surfaces and those attempting to exit from openings where evacuation slides are unusable. It is important that assistance be given to evacuees using ladders to ensure that they safely complete their exit and that any one ladder does not become overloaded.

7-4 Aircraft Forcible Entry.

7-4.1

Aircraft involved in accidents can come to rest in almost any attitude. Any abnormal landing force can jam emergency exits. In other instances the fuselage might be broken open by the impact forces, and doors, windows, and hatches can become dislodged. It is difficult to anticipate the various possible accident conditions, and each incident presents unique problems that must be dealt with. ARFF personnel should be thoroughly trained in forcible entry procedures as well as be provided with a wide variety of tools and equipment necessary to accomplish successful entry and extrication of trapped aircraft occupants. Aircraft rescue and fire fighting personnel training programs should include a discussion of methods to be used for a situation that involves an aircraft in an inverted position. Such training should include crash charts that depict, in plan view, the entire underside of the various aircraft using the airport.

7-4.2

In some instances, entry into an aircraft fuselage can only be gained by cutting through the aircraft skin. Knowledge of the aircraft is required to avoid contact with wires, cables, tubing, and heavy structural members. An area of the aircraft normally clear of these features is located in the upper fuselage area above the windows, and any necessary cutting should be attempted in this area. Caution should be exercised to ensure that cutting operations do not endanger trapped occupants.

7-4.3

Turbine-powered aircraft have heavier skins and structures than the older piston aircraft. Due to this heavy construction, the only practical method of entry, other than using normal or emergency exits, is through the use of portable power tools. These tools take the form of electric, pneumatic, hydraulic, or gasoline-powered cutting, spreading, or shifting equipment. At best, this type of entry into a modern jet aircraft fuselage is very difficult and time consuming. These areas should be depicted on aircraft emergency diagrams. (*See NFPA Aircraft Familiarization Charts Manual*.)

7-4.4

Military combat aircraft present additional hazards due to armament, jettison equipment, and ejection seats. This type of aircraft should always be assumed to be armed. Caution should be exercised in the area at the front of this type of aircraft because it can carry fixed guns and rockets. Unlaunched rockets, when exposed to fire, are dangerous from both front and rear if they ignite. As with any ammunition, keep the rockets cool with foam or water. Further unclassified information should be obtained from the commanding officer of the nearest military installation.

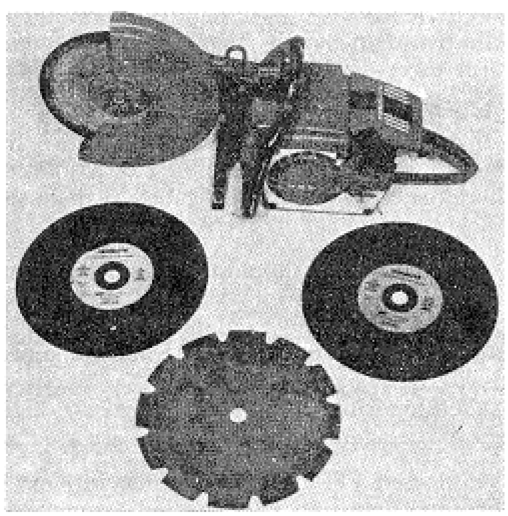


Figure 7-4(a) Rescue saws. Power saws can be used to cut through aircraft skin and structural materials. CAUTION SHOULD BE EXERCISED WHEN USING SPARK-PRODUCING POWER TOOLS WHERE

FLAMMABLE VAPORS EXIST.

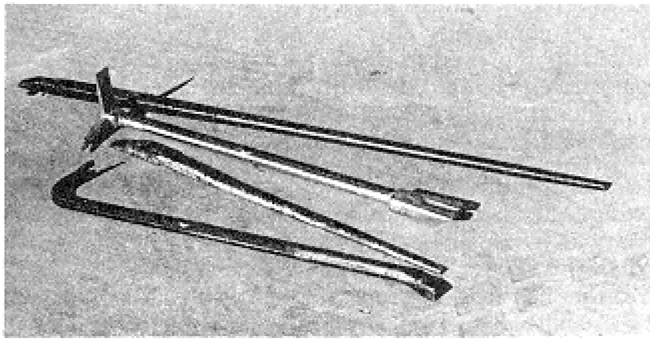


Figure 7-4(b) Prying tools. Claw and pry tools can be used for forcing doors and hatches that are jammed, to pull down panels and partitions, and to dislodge aircraft seats, etc.

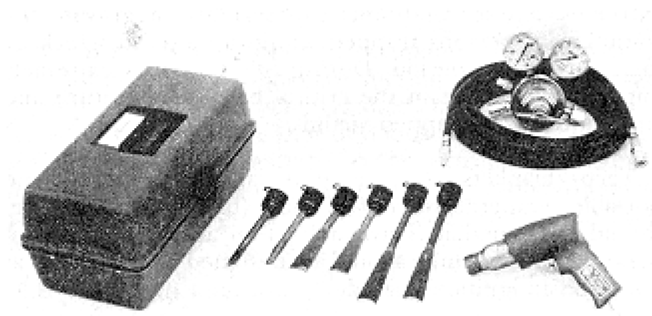


Figure 7-4(c) Air chisel. This tool can be used to cut aluminum and other light metals found on aircraft.

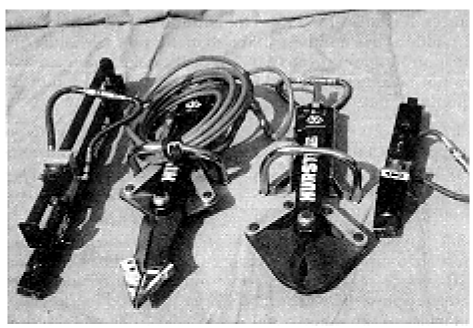


Figure 7-4(d) Hydraulic rescue tool. These tools are used to assist with forcible entry during aircraft accident operations. From left: life or spread (long), spread, cut, and lift or spread (short).

7-5 Extrication and Rescue.

7-5.1

Immediately following the self-evacuation phase of an aircraft accident, a search of the fuselage interior and physical rescue of surviving occupants is crucial. Search and rescue teams should wear full protective clothing and positive pressure self-contained breathing apparatus. They should also be equipped with charged hose lines for their protection and extinguishment of any fire that might have entered the fuselage. A THOROUGH SEARCH OF THE FUSELAGE

INTERIOR AT THIS TIME IS EXTREMELY IMPORTANT. PERSONS, PARTICULARLY INFANTS, CAN BE EASILY OVERLOOKED OR HIDDEN BY DEBRIS.

7-5.2

Rescue operations should be carried out using normal aircraft openings wherever possible. Occasionally, openings caused by airframe separations can be utilized when it is more convenient and safe to do so.

7-5.3

ARFF personnel should have a general knowledge relative to the occupant capacity of the various types of aircraft that use the airport. Initial rescue plans should be based on the assumption that occupant load is at maximum.

7-5.4

The location of occupants in military aircraft can generally be determined by the aircraft type and sometimes by exterior design features such as canopies, gun positions, etc.

7-5.5

Even in survivable aircraft accidents, disruption of the fuselage can be severe, necessitating the improvisation of rescue efforts. ARFF personnel should be skilled in the use of appropriate extrication tools and equipment as well as possessing the basic knowledge and skills to properly stabilize an injured occupant prior to removal from the wreckage.

7-5.6

ARFF personnel rescue and extrication knowledge should include accepted post-aircraft accident procedures, particularly those matters dealing with fatalities and preservation of evidence as described in Chapter 11.

7-5.7

Aircraft accidents can occur during temperature extremes. These conditions can seriously aggravate the condition of persons trapped within an aircraft wreckage for an extended period. During this time it is extremely important to maintain the critical body temperature and vital functions of trapped victims.

Tarps, blankets, portable lights, fans, oxygen units, and portable temperature control units (heating and cooling) should be immediately available at an accident site. Temperature control units should be designed or located so as not to be an ignition hazard.

Chapter 8 Fire Control and Extinguishment

8-1 General.

8-1.1

The risk of fire at an aircraft accident is due to the close proximity of the systems that contain and distribute the fuel and ignition sources such as heated components in engines and undercarriages, damaged electrical circuits, and friction caused by ground slide.

8-1.2

Any post-accident fire can seriously affect the ability of the aircraft occupants to evacuate safely and will reduce the time available to mount a successful fire fighting operation prior to rescue.

8-1.3

Upon impact, or after a period of time, a fire can develop to severe intensity very quickly and can enter the fuselage through opened exits and openings created by the impact.

8-1.4

Aircraft designers are continuously studying design factors and construction material changes that will increase “crashworthiness” and limit the development of fire situations that can impede evacuation. Additional modifications intended to increase the impact survivability of occupants are also being developed. Other changes include improved passenger restraints, reduced combustibility of cabin interiors, better marking of exit routes, upgraded emergency exits, and greater emphasis on the training of flight deck crews.

If these design improvement measures are as successful as anticipated, the prompt and effective intervention by trained ARFF personnel becomes even more important than at present because a greater number of aircraft accident survivors needing assistance can be expected. ARFF personnel should become intimately familiar with all aircraft types using the airport and should pre-incident plan the optimum rescue and fire fighting effort that the fire department can produce with the resources it has at its disposal. Careful consideration of the recommendations in this guide can facilitate the development of practical operational plans.

8-2 Extinguishing Agents for Aircraft Fires.

8-2.1

Aqueous film forming foam (AFFF), film forming fluoroproteins (FFFP), protein foam, and fluoroprotein foam solutions are the primary extinguishing agents preferred for aircraft rescue and fire fighting.

8-2.2

Complementary extinguishing agents consist of approved dry chemicals, Halon 1211, and alternative agents. They are generally best for use on three-dimensional flammable liquid fires or on fires in concealed spaces, such as those occurring behind wall panels, engine nacelles, or wheel wells.

8-2.3

Experience has shown that dry chemical tends to be more effective than halons when used in the open air to extinguish three-dimensional fires, while halons are the preferred agents for electrical fires and in concealed areas.

8-2.4

If dry chemical or halon is used, a fire area, once extinguished, could reflash if exposed to a source of ignition; therefore, a follow-up application of foam is recommended when these agents are used.

8-2.5

AFFF and FFFP should not be mixed with protein-based concentrates. Before film forming foams are used in equipment that formerly contained protein-based foam concentrate, the foam tank and system must be thoroughly flushed with fresh water. The vehicle manufacturer should be consulted to ensure that the agent system design is compatible with the agent to be used.

8-2.6

AFFF and FFFP are compatible with protein and fluoroprotein foams in the applied form and can be applied simultaneously on the same fire area.

8-2.7

AFFF and FFFP agents are compatible with dry chemicals. These agents can be applied simultaneously to improve flame knockdown and control fire spread.

8-2.8

Protein foams should be applied only with compatible dry chemicals. Fluoroprotein foams have demonstrated an improved compatibility with dry chemicals; however, the user should determine that it is adequate to meet operational requirements. If any problems arise, the agent manufacturer should be consulted.

8-2.9

Protein foams should be applied only with compatible dry chemicals.

8-2.10

Fluoroprotein foams have demonstrated an improved compatibility with dry chemicals; however, the user should determine that it is adequate to meet operational requirements. If any problems arise, the agent manufacturer should be consulted.

8-2.11

If foam is being used and the fire is not completely extinguished before the supply is depleted, it might be necessary to complete extinguishment with water streams. When this occurs, avoid applying water or walking in any area that has been secured with foam, as it can break down the established vapor seal that the foam blanket provides.

8-2.12

If the fire has not been completely extinguished by foam, the secured area will “burn back” at a rate that is dependent on the stability of the foam being used. Also under certain circumstances, fire can “flash back” over a portion of an area covered by foam.

8-3 Water and Agent Resupply and Conservation.

Auxiliary water tankers should be dispatched whenever there is any indication of possible need and especially when the aircraft accident site is known to be beyond water relay capability. Prearrangements should be made to ensure that additional supplies of extinguishing agents are brought to the scene. Prudent utilization of agents under these circumstances is particularly important, and application methods should be carefully selected to ensure their most effective use.

8-3.1

It is considered impractical to require airport authorities to provide quantities of extinguishing agents to deal with the worst situation that could arise using only the equipment located on the airport. Therefore, it is necessary for airport emergency plans to contain instructions for requesting support from externally-based fire services following an emergency. It is not easy to specify an operational requirement which makes adequate provision in all circumstances. It is clear that a need for additional water could arise in as little as five minutes, although in this time the initial fire situation should be greatly reduced. If total extinguishment has not been achieved the fire can quickly extend and the equipment must be replenished.

8-3.2

Airports should consider providing additional water as a support facility. There might be exceptions where airports have adequate piped, stored, or natural water supplies, provided that these are available at an accident in sufficient quantity and in time to meet the operational requirement.

8-3.3

In each case the authority having jurisdiction should consult closely with the Chief Fire Officer of the Mutual Aid Fire Service regarding response and supply of additional water supplies. The airport authority will need to assess the suitability of the water resources which can be mobilized to support the airport fire service when a serious and prolonged post-accident fire occurs. Therefore, the speed of mobilization and the rate at which the water can be delivered to the accident site are important factors.

8-4 Rescue Operations.

8-4.1

The primary objective of ARFF personnel at the scene of any aircraft accident is to control and extinguish the fire to enable safe evacuation of the aircraft.

8-4.2

Occupant survival is generally limited to aircraft accidents that are of low impact in nature, where the fuselage is not severely broken up and a fuel fire has not developed. In more severe accidents, even those where fire does develop, ARFF personnel should assume that there is always the possibility of survivors and take aggressive steps to control the fire, initiate evacuation, and rescue those unable to self-evacuate.

8-4.3

Rescue operations should begin as soon as conditions permit and often are a simultaneous function during the fire fighting phase that requires considerable coordination. The rescue team’s mission includes assisting evacuees, accomplishing forcible entry if necessary, completing interior extinguishment, extricating trapped survivors, and removing the injured to safety.

8-4.4

One rescue team method consists of four ARFF personnel equipped with full protective clothing and positive pressure self-contained breathing apparatus (SCBA). Two of the persons are handline operators and precede the other two, who are equipped with appropriate hand-held tools needed for forcible entry, extrication, and making access to hidden fuselage fires behind panels, floors, and compartments.

A procedure preferred by some fire departments is to provide an additional handline operator, similarly attired and equipped with SCBA, operating behind the rescue team with a spray stream, as their protection throughout the entire operation.

8-5 Size-Up (Risk Assessment).

8-5.1

The process called size-up (risk assessment) merely means the gathering of facts in preparation for making decisions. The facts pertaining to an aircraft accident, when mentally assembled, enable the responsible ARFF officer to establish both initial tactics and overall strategy.

8-5.2

The size-up (risk assessment) process is initiated by the first-responding ARFF officer and is carried on throughout the duration of the incident in terms of depth and scope by later-arriving superior officers.

8-5.3

When an aircraft accident occurs, some size-up (risk assessment) information in the form of established facts should be immediately known as the result of training, pre-incident planning, knowledge of available resources, and interpretation of alarm information. Additional facts become known through observation during response and upon arrival at the scene.

8-5.4

Vital operational decisions based upon initial size-up (risk assessment) information should be made without delay. Realistic objectives are critical, and consideration should be given to the capabilities of resources that are immediately available.

8-5.5

Initial assignments of tasks based on the size-up (risk assessment) are generally not fixed and tend to be modified as the incident develops. The size-up (risk assessment) process should continue throughout the duration of the incident, and any changes in strategy or objective that develop should be communicated to key personnel involved in the operation.

8-6 Aircraft Accident — Fire Involvement.

8-6.1

In an aircraft accident, occupants are confined within the fuselage and are surrounded by very large amounts of fuel that, when ignited, can release heat at about five times the rate that develops in the typical structure fire. An aircraft fuselage has a very low resistance to fire, except for engine areas, cargo compartments, and galleys, as fire and smoke barriers are nonexistent.

8-6.2

The priority should be given to aircraft occupant survival. Those who have survived the impact forces then face the exposure to fire and toxic products of combustion. Total extinguishment of the fire is an acceptable initial approach if it is determined to be the most effective method of successfully accomplishing rescue. A resource-conserving alternative would be selective control of fire in areas where occupants are successfully evacuating and maintaining these escape routes until it has been determined that evacuation is complete. A decision as to the precise method of initial fire attach should be made by the ARFF officer in charge immediately upon arrival at the scene. All members of the ARFF team should realize that initial plans are always subject to change and should remain alert for orders that alter operations as conditions dictate.

8-6.3

If upon arrival at an aircraft accident the operator of the first-arriving ARFF vehicle encounters a small fire, the best tactic would be to extinguish it rapidly and then begin to blanket any fuel spill with foam. Later-arriving vehicles should assist in the foam application if needed or perform other tasks as directed by the officer in charge.

8-6.4

If a large fire is in progress upon arrival of the ARFF personnel, foam should be applied using the vehicle turrets. Since initial foam supplies can be exhausted in 2 minutes, turret operators should understand that foam application by this method must be effective and that streams should be shut down on occasion to assess progress and conserve foam. Once a fire has been controlled and any fuel spill blanketed with foam, consideration should be given to employing foam handlines that are more maneuverable and therefore more effective for maintaining a foam blanket and extinguishing small fires.

8-6.5

If foam becomes contaminated by fuel splashing into it, then at some time the foam will become flammable. The degree to which this is a problem depends on the type of foam and the amount of contamination. As solution drains from the foam, the water drains at a faster rate than the fuel, resulting in a fuel-rich foam matrix that can ignite if exposed to a source of ignition. This problem is more evident in AFFF than in other foams because it has a much faster drainage rate and becomes flammable at a lower level of contamination.

8-6.6

Protein and fluoroprotein foaming agents should form a blanket over the surface of a flammable liquid fire in order to extinguish it. The foam should be applied using a dispersed pattern over the surface of the burning fuel to completely cover the spill area. It needs to be applied in such a manner that it does not break up any previously established blanket. If isolated openings in the foam blanket occur, they should be filled in as soon as possible with new foam.

8-6.7

AFFF and FFFP agent solutions can be applied either with aspirating nozzles, turret nozzles used for protein and fluoroprotein foams, or conventional water spray nozzles. Either spray or straight streams can be used as the situation dictates. It is best to approach the fire area as closely as possible and apply the foam in a wide spray pattern initially, changing to a narrower pattern after the heat has been reduced. The stream should be applied in a gentle manner to avoid unnecessary plunging of the stream into the burning fuel. The foam should be applied to the near edge of the fire with a rapid side-to-side sweeping motion to distribute the foam rapidly and thinly over the burning fuel. Advance as the fire is controlled, always applying the foam to the nearest burning fuel surface. Advance only after a continuous, unbroken foam cover is established. The entire foam blanket integrity should be maintained to compensate for voids created by movements of ARFF personnel, evacuees, and equipment, as well as the normal draindown of the foam.

8-7 Extinguishment Techniques.

8-7.1

Vehicle approach to a burning aircraft should be such that turret streams can be applied along the length of the fuselage with efforts concentrated on driving the fire outward while keeping the fuselage cool, protecting occupants as they evacuate, and assisting with the entry of rescue teams.

8-7.2

The location of survivors, if known, and the area of fire will determine where the first streams should be applied. If the fire has penetrated the fuselage, a direct interior attack with handlines should be initiated as soon as possible.

8-7.3

Where it is compatible with the evacuation process, it is best to approach an aircraft fire from the windward side. Agents should be applied from the windward side to provide better reach and greater ability to monitor extinguishing effectiveness, as the heat and smoke will be moving in the opposite direction. When vehicle turrets are in operation on opposite sides of a fuselage, care should be taken so that the fire is not driven underneath from one side to the other.

8-7.4

When an aircraft comes to rest on sloping terrain or adjacent to a gully or wash, circumstances permitting, the fire should be approached from high ground and the burning fuel driven away from the fuselage.

8-7.5

Aircraft accidents do not occur under the best conditions or permit the ideal conditions for combating a fire. It will not always be possible to approach the fire from high ground or the windward side. What is important is an aggressive attack to isolate the fuselage from the fire and efficient fire ground coordination to achieve a successful evacuation of occupants and complete fire extinguishment.

8-7.6

The initial attack on an aircraft fuel fire should normally be by judicious application of foam, or alternatively by the combined use of foam and a complementary agent. A three-dimensional or flowing fire should be extinguished by using an approved dry chemical, Halon 1211, and alternative agents, followed by an application of foam. Even where foam alone is used, a suitable complementary agent should be available to deal with fire inaccessible to direct foam application.

8-7.7

If a fire threatens exposed aircraft, structures, or other combustibles, they should be protected by foam or water spray.

NOTE: Water streams or runoff should not be permitted to destroy any foam blanket in the critical fire area.

8-7.8

If a large fuel spill occurs without igniting, it is important to eliminate as many ignition sources as possible while the spill is being stabilized with a foam blanket. There can be enough residual heat present in jet engines to ignite fuel vapors 30 minutes after shutdown.

8-7.9

Extinguishing agents should be applied in a manner to avoid spot cooling of components that can cause stress failure and disintegration. If possible, streams should be employed so that even surface cooling can result. Approved dry chemicals, Halon 1211, and alternative agents can extinguish fires involving hydraulic fluids or lubricants, but they lack the cooling ability necessary to prevent reignition.

8-8 Turret Operations.

8-8.1

ARFF vehicles should be positioned to make the most effective use of all extinguishing agent systems. The most efficient use can require movement of the vehicle during turret or even handline operations. It is vitally important not to waste available agent. TURRETS SHOULD BE USED ONLY AS LONG AS THEY ARE BEING EFFECTIVE. After initial knockdown of the heat and flame, use of handlines to maintain control of evacuations areas can be the key to a successful rescue operation.

8-8.2

When selecting vehicle positions for applying foam from a turret, remember that wind has a considerable influence upon the quality of the foam pattern and the rate of fire and heat travel. Utilize the wind whenever possible to achieve more effective fire control.

8-8.3

Turret application should never be directed so as to drive fuel or fire toward the fuselage. The main objective is to maintain an escape route for occupants until complete evacuation is achieved.

8-8.4

Usually water supplies are a key factor, and turret operators should concentrate their extinguishing efforts on the escape route from the aircraft.

8-8.5

The “pump and roll” concept, a method of applying agent from a turret while the vehicle is in motion, can be a very effective fire control technique when used correctly.

8-9 Aqueous Film Forming Foam (AFFF) and Film Forming Fluoroprotein (FFFP) for Turret Application.

8-9.1

The basic principle is to distribute a visible AFFF or FFFP blanket of sufficient thickness over the burning fuel to act as a blanket for vapor suppression. The original blanket should not be relied upon to be permanent and should be maintained as necessary until the fuel vapor hazard no longer exists.

8-9.2

Both aspirating and nonaspirating nozzles can be used for AFFF or FFFP application. A nonaspirated nozzle typically provides longer reach and quicker control and extinguishment. However, expansion rates and foam drainage times are generally less when AFFF or FFFP is applied with nonaspirating nozzles, and it should be understood that the foam blanket might be less stable and have a lower resistance to burnback than that formed using aspirating nozzles.

Manufacturers should be consulted for guidance on nozzle performance. Extreme caution should be taken when using the straight stream method as this can cause an increase in the liquid pool surface or cause an opening in the foam blanket, releasing flammable vapors.

8-10 Protein and Fluoroprotein Foam Turret Application.

8-10.1

Protein and fluoroprotein foams should be applied to burning fuel so that they gently form a uniform and cohesive blanket with the least possible turbulence to the fuel surface.

8-10.2

Aspirating nozzles should be used for applying protein and fluoroprotein foams in either the straight stream or dispersed patterns to distribute the foam over a wide area. When using the straight stream method of application, the foam should be applied indirectly using deflection techniques, and special care should be exercised to avoid disturbing the established foam blanket.

8-11 Handline Foam Application.

8-11.1

As soon as the fire has been knocked down by turrets, they should be shut down, perhaps repositioned, and held in a state of readiness to resume operation should the need occur. During this phase of rescue and fire fighting, handlines are more effective than turrets in controlling the fire, maintaining rescue paths for occupants, mopping up spot fires, maintaining the foam blanket, and conserving vital agent supply.

8-11.2

Whether or not there is an immediate need for them, charged handlines should be placed in strategic positions as soon as possible after ARFF personnel arrive on the scene. This practice would ensure their immediate availability for use when the need arises.

8-11.3

Foam application principles are the same for handlines as they are for turrets.

8-12 Aircraft Accident — No Fire Involvement.

At an aircraft accident without fire, appropriate fire prevention measures should be initiated immediately.

(a) All spilled fuel should be covered with foam. Engines and other heated surfaces should be cooled with foam or water fog to prevent ignition. Care should be taken so that the seal established by the foam blanket is not washed away or diluted by the water spray.

(b) The washing of spilled fuel from around the aircraft requires caution. Raw fuel and flammable vapors should be directed away from sources of ignition.

(c) Every effort should be made to prevent sparks whenever there is the possibility of exposed fuel or fuel vapors in the area. Particular care should be taken to prevent sparks due to arcing before the aircraft electrical system can be de-energized.

(d) ARFF need to exercise extreme care when cutting tools are used at the accident site when fuel liquid and vapor is present. A support fire-fighter should be on standby with a fully-charged hoseline to deal with any incipient fire that might develop.

8-13 Exposure Protection.

8-13.1

After rescue of occupants, protection of exposed property should be the next consideration at the scene of an aircraft accident, whether fire exists or not. In addition to airport structures and other aircraft, plans should include preventing contamination and fire spread into drains, sewers, waterways, and any below ground facilities. Authorities should be immediately notified of any exposure to fire or contamination involving property under their control.

8-13.2

Early and effective fire extinguishment ensures the least amount of property loss, and that includes exposed properties whether involved in fire or not. Where resources are limited, conditions will dictate which exposures receive first priority for protection.

Chapter 9 Interior Aircraft Fires

9-1 General.

9-1.1

The recommendations contained in this chapter are provided for the guidance of ARFF personnel encountering interior aircraft fires occurring in both parked, unoccupied aircraft and aircraft with passengers and crew aboard.

9-1.2

The occurrence of interior aircraft fires where passengers and crew are onboard presents a major problem for ARFF personnel. An acute life safety hazard exists in these instances, and the ability to enter the aircraft and extinguish the fire might have to be delayed until evacuation has been completed. Because forcible entry and rescue are discussed in detail elsewhere in this guide, they will not be covered here, and instead emphasis will be on the procedures and techniques of attacking and extinguishing interior aircraft fires.

9-1.3

Aircraft passenger cabin fires normally involve ordinary combustibles such as upholstery, paneling, carpeting, refuse, electrical insulation, and carry-on materials. Generally, a direct attack on the fire with water streams, using structural fire fighting techniques, is effective.

9-1.4

ARFF personnel should understand the structural characteristics of an aircraft fuselage. The absence of fire stops at the floor, behind wall panels, and above ceiling areas permits fires to spread undetected and unchecked through combustible materials once fire has entered those areas. ARFF personnel should always assume, until it is proven otherwise, that fire has moved away from its origin via these concealed spaces. Sections of flooring, wall panels, and ceilings should be removed where fire travel is suspected so that complete extinguishment can be accomplished.

9-1.5

Since the burning of aircraft interior materials creates a toxic atmosphere, ARFF personnel should wear positive pressure self-contained breathing apparatus whenever working inside the fuselage both during the fire fighting stage and later, while overhauling. Additionally, the entire fuselage should be ventilated as quickly as possible by whatever means available. Smoke ejectors can expedite horizontal ventilation, which is usually the only choice of methods since aircraft have no designed vertical openings. [*See Figure 9-5(b).*]

9-1.6

Interior aircraft fire situations can differ widely; therefore, explicit guidance regarding extinguishment techniques is not possible. Points of entry and methods of attack should be dependent upon an evaluation of conditions and assessment of resource capability by the ARFF officer in charge.

9-1.7

An interior aircraft fire location and its intensity can to some degree be determined by observation through cabin windows, smoke characteristics, or aircraft skin that shows buckling or paint blisters.

9-1.8

In the event that an interior aircraft fire cannot be immediately extinguished, foam or water spray should be applied to wing and fuselage fuel tank areas that might be exposed to heat.

9-2 Aircraft Interior Fires Occurring in Flight.

9-2.1

A major hazard of commercial aviation is the in-flight fire that cannot be controlled by onboard portable extinguishers or fixed extinguishing systems.

9-2.2

Aircraft emergency landings or accidents can be the result of uncontrolled fires occurring in flight. The most frequent types of in-flight fires involve:

(a) Engines,

(b) Cabin areas,

(c) Lavatories,

(d) Heaters,

(e) Cargo areas, and

(f) Electrical compartments.

9-2.3

Portable fire extinguishers are required to be mounted at specific locations in the cabin of passenger aircraft, and flight deck crews receive periodic training in their use. The extinguishers are designed to handle incipient fires in accessible areas. However, fires can and do originate in locations not readily accessible from the cabin while the aircraft is in flight. If the area involved in fire is isolated and is not equipped with a fixed extinguishing system, a serious fire can develop and spread rapidly.

9-2.4

When an uncontrolled in-flight fire occurs, the aircraft must make an emergency landing at the nearest suitable airport, and the occupants must be evacuated before being overcome by heat, smoke, and toxic gases. ARFF personnel are usually notified of such emergencies well in advance of the landing and should be prepared to assist in the immediate evacuation and to enter the aircraft and extinguish the fire.

9-2.5

When the aircraft is on the ground and whether or not the air conditioning system is operating, heat, smoke, and gases will build up, creating a toxic atmosphere and setting the stage for a flashover.

9-2.6

After the aircraft has landed and the flight deck crew has initiated emergency evacuation, it should be assumed that some of the occupants might not have the ability to self-evacuate. ARFF personnel should allow normal procedures to be carried out to their full potential without compromising the evacuation process; however, ARFF personnel and vehicles should be placed in strategic positions to effect entry into fuselage to confirm complete evacuation and achieve fire control.

9-2.7

If there is no evidence of occupant evacuation, immediate steps should be taken to make entry for control of the fire and rescue of occupants. Entry will permit an inrush of fresh air into a possibly overheated or unstable atmosphere that could rapidly accelerate the fire. Toxic gases will be present, so ventilation and a thorough search for survivors should take place immediately and simultaneously with the fire fighting effort. In darkness or heavy smoke conditions these efforts will be much more difficult.

9-2.8

Extinguishing agents other than water that can be used on interior aircraft fires include foam, halons, and dry chemicals. However, if onboard oxygen systems have been damaged, creating an oxygen-rich atmosphere, or if there is major interior fire involvement, water streams would be the best agent.

9-3 Interior Fires in Unoccupied Aircraft.

9-3.1

Fires occurring in unoccupied aircraft often result in delayed detection. An unattended aircraft with its doors closed can contain a smoldering fire that can burn unnoticed for an extended period of time. Under these conditions, a build-up of extremely hot fire gases can develop as the fire consumes all the available oxygen. Opening up an aircraft under such circumstances can be very hazardous because when oxygen is introduced into such an atmosphere the entire interior can become immediately ignited, possibly with explosive force. Handlines that fully-charged need to be in place prior to entry into the fuselage.

9-3.2

When arriving at a closed, unoccupied aircraft that is suspected of having an interior fire, the internal atmosphere should be assessed before entry is attempted. If flame cannot be seen, and the windows are hot to the touch and obscured by heavy smoke, it can be expected that a hot, smoldering fire exists and entry of outside air at this time would ignite the entire interior.

9-3.3

If an interior fire in an unoccupied aircraft has not reached the smoldering stage, there is sufficient oxygen present and a free-burning fire can be maintained. Under these circumstances entry should be made and the fire extinguished with water in the conventional manner.

9-3.4

Extinguishment of a hot, smoldering, internal aircraft fire can be very difficult. Where this type of fire exists, one method is worth consideration. It can be referred to as an indirect attack that is made from small fuselage openings such as slightly opened exits or openings made in cabin windows. A coordinated multiple-point attack is more effective than a single point attack and is a necessity when applying the method to fires in wide-body or jumbo aircraft with large volume interiors. It must be remembered that this method is not suitable if there is any possibility of occupants being onboard the aircraft.

9-3.4.1 The extinguishment principle of this indirect method is based on the conversion of water spray into steam as it contacts the super heated atmosphere within an enclosure. The rapid expansion of water spray droplets into minute stream droplets increases the surface area of the water, permitting it to absorb more heat, thus making it more efficient as a cooling agent. Water in this form and under pressure has the ability to penetrate dense burning materials and enter areas behind panels and coverings. When properly applied the method lowers the temperature of the entire fire area to a point where combustion ceases.

9-3.4.2 Should a smoldering, interior aircraft fire occur in compartments below the passenger and flight deck levels, the indirect attack method can also be applied, adapted to the particular circumstances involved. More difficulty can be experienced in achieving convenient openings in these compartments, however. Consideration should be given to attacking fires in these areas through openings in the cabin floor.

9-4 Penetrating Nozzles.

9-4.1

The use of penetrating nozzles is another way of combating aircraft cabin and compartment fires. Most penetrating nozzles are designed so that any agent currently used by ARFF providers can be utilized.

9-4.2

To extinguish an aircraft cabin or compartment fire using penetrating nozzles, the total fire area requiring agent application needs to be considered. For example, to extinguish a large fire in the cabin of a wide-body aircraft, penetrating nozzles injecting agent simultaneously from dispersed, multiple injection points would be required to provide a sufficient amount of agent to effect extinguishment in a timely manner.

9-4.3

Currently, there are a number of penetrating nozzles in use. The manner of application can be slow, awkward, and occasionally dangerous when applied to aircraft fire fighting and should be done with great care. When using this type of penetrating nozzle, ARFF personnel should make certain that they have proper footing and sufficient operating, and have an understanding of aircraft design and construction and emergency access points of entry. (*See Figure 9-4.3*.)

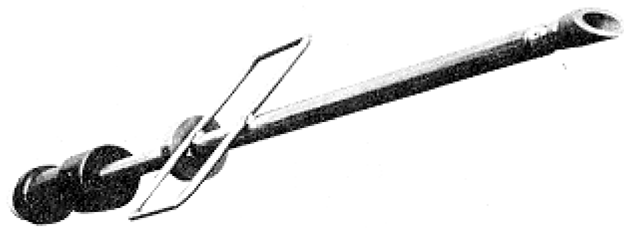


Figure 9-4.3 Aircraft skin penetrator nozzle.

9-4.4

More recently a new type of penetrating nozzle concept has been introduced by the U.S. Air Force. It is referred to as a skin penetrating agent applicator tool (SPAAT). This tool incorporates a pneumatic device that drills through aircraft skin and windows within 10 seconds and can immediately inject any of several agents into the fuselage. (*See Figure 9-4.4*.)

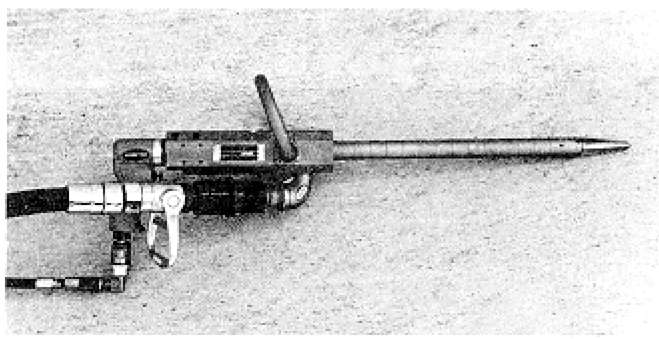


Figure 9-4.4 Skin penetrator agent applicator tool (SPAAT).

9-5 Interior Aircraft Fire Overhaul.

During the overhaul phase of an interior aircraft fire, hose lines should remain charged and available to extinguish any deep-seated fire, hidden uncovered fire, or reignition. Carpeting, wall panels, partitions, and ceiling covering should be removed when necessary to ensure that all fire is extinguished and that there is no threat of reignition. The use of portable lighting units and smoke ejectors will help to make the aircraft interior safer and more tenable for ARFF personnel. [*See Figures 9-5(a) and (b)*.] ANY PERSON ENTERING THE AIRCRAFT DURING THE OVERHAUL PHASE SHOULD USE POSITIVE PRESSURE SELF-CONTAINED BREATHING APPARATUS.

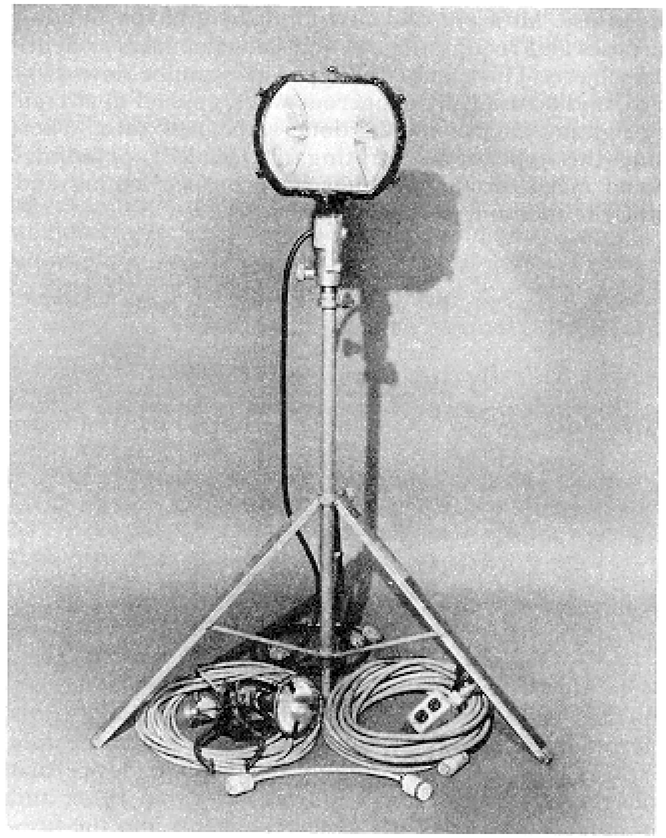


Figure 9-5(a) Portable lighting units.

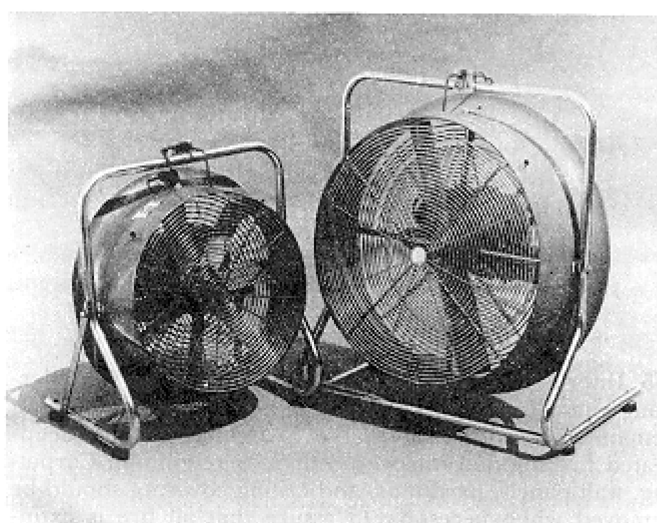


Figure 9-5(b) Smoke ejectors.

Chapter 10 Miscellaneous Aircraft Incidents

10-1 General.

10-1.1

Each year ARFF personnel respond to numerous incidents on airports that are considered "minor." These seemingly routine activities do not make headlines, but the absence of intervention could often result in catastrophic loss of life, serious injuries, and extensive property loss.

10-1.2

Guidance presented in this chapter is intended to inform ARFF personnel of a variety of aircraft incident types and how to deal with them so that the hazards relative to aircraft operations on airports can be safely abated.

10-2 Engine Fires.

10-2.1

It is reasonable for ARFF personnel responding to aircraft engine fires to expect that the following actions have probably been accomplished by the flight deck crew:

(a) Engine shut down;

(b) Engine fire extinguishing system (if any) activated;

(c) Electrical power to the affected engine(s) de-energized; and

(d) Fuel and hydraulic fluid supply to the affected engine(s) shut down.

These actions should be verified as conditions permit. It should be emphasized that turbine engines, following shutoff of power and fuel, can remain a potential hazard during "wind down" with high heat retention continuing for as long as 30 minutes. This heat constitutes a potential ignition source for flammable vapors. On propeller-driven or rotary-wing aircraft, contact with propellers, or entry into their path of rotation, should be avoided during all stages of the emergency.

10-2.2

When jet engines are started or shut down in certain wind conditions, hot starts or tail pipe fires can occur. These fires can usually be controlled by the flight deck crew. In some cases, however, fire department intervention might be necessary.

10-2.3

When reciprocating engine fires are confined within the nacelle, but cannot be controlled by the aircraft extinguishing system, dry chemical or a halon agent should be applied first, as these agents are more effective than water or foam for fires inside an enclosure. Foam or water spray should be used to cool the outside of the nacelle.

10-2.4

Fires confined to the hot section of jet engines can be best controlled by keeping the engine rotating. Such action should be considered in the context of necessary aircraft evacuation and other safety considerations. Fires outside the combustion chambers, but confined within the nacelle, are best controlled with the engine's fixed extinguishing system. If the fire continues after the system has been exhausted, or if reignition occurs, a halon or dry chemical agent should be applied through maintenance openings. The aircraft operator should be advised of the type of extinguishing agent used in order that appropriate maintenance action can be taken later.

10-2.5

Foam or water should not be applied to either the intake or exhaust of a jet engine unless control cannot be secured or confined to the engine nacelle using halon or dry chemical. If foam or water is applied to either the intake or exhaust, ARFF personnel should stand clear to avoid being struck by disintegrating engine parts.

10-2.6

Most jet engines are constructed with magnesium and titanium parts that, if ignited, are very difficult to extinguish. If these fires are contained within the nacelle, they should be permitted to burn themselves out as long as:

(a) There are no external vapors present that cannot be eliminated; and

(b) Sufficient foam or water spray is available to maintain the integrity of the nacelle and surrounding exposed aircraft components.

10-2.7

When tail pipe fires occur in the elevated center engine of three-engine wide-body aircraft or a B-747 auxiliary power unit, special elevating equipment might be required to effectively discharge agent on the fire. (*See also Appendix B.*)

10-3 Aircraft Fuel Servicing Incidents.

10-3.1

A number of aircraft fires have occurred during fuel servicing. Ignition has been caused by static developed in flowing fuel, surface-generated static within an aircraft fuel tank, or refueling vehicle, defective fuel pumps, an external source of ignition, and other improper fueling procedures. Defueling and fuel transfer operations are also serious fire potentials. Standards relative to aircraft fueling procedures and proper equipment maintenance should be diligently enforced by the authority having jurisdiction on the airport.

10-3.2

Fuel spills exterior to the aircraft should be handled in the manner described in NFPA 407, *Standard for Aircraft Fuel Servicing*, when fire does not occur. If fire does occur, it should be handled similar to any other aircraft accident, with primary emphasis on life safety. The practice of fueling occupied transport category aircraft necessitates that, in the event of a fuel spill fire, an immediate check of the interior for occupants is imperative.

10-3.3

Many transport category aircraft have ganged fuel tank vents near wing tips. Vented JET A type fuel (kerosene grades) vapors normally present very little hazard. If tanks are overfilled, the fuel will discharge through the vents, causing a fuel spill. There is a greater potential for a flammable vapor-air mixture being present in the immediate vicinity of wing tip vents when JET B fuel is used. Regardless of which fuel is used, it is good practice not to position or operate vehicles within a 25-ft (8-m) radius of aircraft fuel system vent openings.

10-4 Hot Brakes and Wheel Fires.

10-4.1

The heating of aircraft tires causes overpressure and presents a potential explosion hazard. Good judgment should be exercised in determining the severity of the situation, and this information should be conveyed to the flight deck crew. The flight deck crew in turn can assist the rescue and fire fighting effort by performing necessary procedures (i.e., shut down engines, extend flaps, prepare evacuation, etc.).

10-4.2

In order to avoid endangering ARFF personnel and aircraft occupants and causing unnecessary damage to the aircraft, it is important not to mistake hot brakes for brake fires. Hot brakes normally cool by themselves and do not require an extinguishing agent.

10-4.3

When a hot brake condition occurs on a propeller-driven aircraft, it is usually beneficial to keep the propeller operating that is directly forward of the wheel with hot brakes until the brakes have cooled. Larger, modern aircraft have fusible plugs mounted in the wheels that fuse at approximately 300°F–400°F (282°C–382°C), allowing the tires to deflate before dangerous pressure can develop.

10-4.4

ARFF personnel should remain clear of the sides of aircraft wheel assemblies that are involved in fire and approach only in a fore and aft direction. Since heat is transferred from the brake to the wheel, extinguishing agent should be applied to the brake area. The primary objective is to prevent the fire from spreading upward into the wheel wells, wings, and fuselage.

10-4.5

Foam, water spray, halons, and dry chemical are effective agents for direct application on brake fires.

10-4.6

Dry chemical agents and Halon 1211 might extinguish fires involving hydraulic fluids and lubricants, but reignition can occur since these agents lack sufficient cooling effect. Halon 1211 is particularly effective in extinguishing undercarriage fires; however, where magnesium wheel components are burning, halon agents should not be used.

10-4.7

Effectiveness of any gaseous extinguishing agent can be severely reduced if wind conditions are such that sufficient concentration cannot be maintained to extinguish the fire.

10-4.8

Solid streams of water should be used only as a last resort on wheel fires since the rapid cooling can cause an explosive failure. However, fires involving magnesium wheels have been successfully extinguished by applying large amounts of water from a distance. This method rapidly reduces the heat to a point below the ignition temperature of the magnesium, and the fire is extinguished. ARFF personnel should exercise extreme caution when this method of extinguishment is used, as explosive failure of the wheel components is likely.

10-5 Combustible Metal Fires.

Burning magnesium or titanium parts should be isolated if possible and extinguished by applying a Class D agent. Covering the burning metal with dry, uncontaminated sand can be effective when a Class D agent is not available.

10-6 Broken Flammable Liquid Lines.

Broken fuel, hydraulic, alcohol, and lubricating oil lines should be plugged or crimped when possible to reduce the amount of spill potential.

10-7 Heater Fires.

Heaters located in wings, fuselage, and tail sections of aircraft can be protected with a fixed fire extinguishing system. It can be assumed that in the event of an airborne heater compartment fire, the system would have been activated. After the aircraft has landed, a thorough check of the heater compartment and surrounding area should be made to ensure that there has been no reignition or spread of fire.

10-8 Bomb Threats/Security.

10-8.1

Threats of terrorism have forced airports to enforce strict security measures. These frequently impact the operation of the emergency services.

10-8.2

Arrangements must be made between the airport security authorities and mutual aid responders to enable them to obtain immediate access to the accident site. Care must be taken to ensure that only authorized persons are admitted when a security gate is being used.

10-8.3

When a bomb threat involving an aircraft is declared an emergency, the aircraft should be evacuated without delay. Passengers should be directed to leave their carry-on materials and depart the aircraft as quickly as possible. The situation might dictate the use of the emergency evacuation slides or built-in stairs. Portable stairways positioned by ARFF personnel should be the safest and most practical alternative.

10-8.4

Immediately after evacuation has been completed, the aircraft involved should be moved to a location at least 1000 ft (300 m) away from structures and other aircraft if not already so located.

10-8.5

Airport pre-incident plans should incorporate assignment of initial responsibility in any bomb threat emergency for initiating protective measures, conducting and controlling any search activities, transferring their responsibility, and declaring the termination of the emergency.

10-8.6

The role of the ARFF personnel in bomb threat emergencies should be limited to:

(a) Assisting occupants evacuate the aircraft;

(b) Assuming a standby status and remaining in readiness after evacuation is complete and the aircraft has been moved to a safe location; and

(c) In the event of a bomb detonation, assuming command and control of any rescue operation or fire incident that results.

10-8.7

The airline, where involved, should have the responsibility for the safety and well-being of the passengers and should cooperate and assist the airport police in any needed search of baggage or aircraft.

10-9 Incidents Where Aircraft Fire Warnings Occur.

10-9.1

It is often difficult for the flight deck crew to accurately appraise conditions following actuation of an aircraft fire warning indicator. Therefore, the aircraft should be brought to a stop after clearing the runway and before approaching the terminal. ARFF personnel should inspect the affected area by checking for external evidence of smoke or heat. If no evidence exists, the aircraft should continue on to the terminal where a more thorough inspection can be made.

10-9.2

If there is evidence of fire, immediate access should be made and the fire extinguished. If this occurs the aircraft should be shut down and the decision made as to whether an evacuation of occupants should take place. Airline maintenance personnel and equipment should be requested to respond and assist ARFF personnel in gaining access and operating ground power units, and should assist with portable stairways if needed for evacuation.

10-10 Emergency Landings.

10-10.1

Often, landing gear stuck in the retracted position is the result of broken hydraulic lines or loss of electrical power. Spilled hydraulic fluid can ignite in the wheel wells due to the presence of electrical shorts, friction sparks due to a wheels-up landing, or other heat sources. Should ignition occur, the fire has a tendency to travel up into the fuselage and can rapidly become a major interior fire. ARFF personnel should take immediate steps to ensure the stabilization of this problem even though appearances from the exterior do not immediately indicate the presence of fire.

10-10.2

Hydraulic problems on landing aircraft can involve the brake systems, flaps, spoilers, etc. This has a tendency to lengthen the rollout after touchdown and can also affect the aircraft's directional control. As soon as the aircraft has touched down and passes each ARFF vehicle that is standing by, that vehicle should immediately follow the aircraft and be ready to perform any necessary operation when it comes to a stop. **IT IS EXTREMELY IMPORTANT THAT ALL OTHER AIRPORT VEHICLES AND PERSONNEL REMAIN CLEAR OF THE AIRCRAFT, THUS PERMITTING ARFF VEHICLES AND PERSONNEL TO MANEUVER AND POSITION FOR EFFECTIVE RESCUE AND FIRE FIGHTING**.

10-10.3

At emergencies involving landing gear malfunctions or tire problems, there is always a possibility of the aircraft veering off the runway after landing and hitting standby ARFF vehicles. It is difficult to predict the touchdown point. Therefore, if there are two or more ARFF vehicles available, one vehicle should stand by on the opposite side of the runway, a suitable distance from the edge.

10-11 Aircraft Accidents in the Water.

10-11.1

Many aircraft accidents in the water have occurred in the critical response area off the end of the runway. Where runways terminate adjacent to a significant body of water, special provisions should be made to ensure the rapid response of ARFF services. For any aircraft overrunning or landing short of the runways, response times should be as close as possible to those of land emergencies.

10-11.2

Many transport category aircraft not engaged in intercontinental overwater flights are equipped only with flotation-type seat cushions as emergency flotation devices. Survivability of passengers using this equipment is limited. Survivors are susceptible to hypothermia in water below 70°F (52°C) and ingestion of vapors from floating fuel. Rapid response is extremely important.

10-11.3

In water landing accidents, the possibility of fire is normally reduced because of the cooling of the heated surfaces by the water. In situations where fire occurs, chances of its control and extinguishment are minimal unless the accident occurs within close proximity to shore and extinguishing operations can take place at close range.

10-11.4

Where the distance offshore is within range, fire hose can sometimes be floated into position by scuba divers or boats and used to supplement other means of fire attack.

10-11.5

The impact of an aircraft into water can rupture fuel tanks and lines. It is reasonable to assume that fuel is floating on the water surface. Watercraft having exhausts at or above the waterline can present an ignition hazard and should not enter the area. Advantage should be taken of wind and water currents when dealing with floating fuel. Every effort should be made to keep it from moving into areas where it would be hazardous to rescue operations. As soon as possible, pockets of fuel should either be broken up, moved away with large velocity nozzles, covered with foam, or disposed of by commercial reclaiming enterprises. The local water pollution control agency can be of assistance during this operation.

10-11.6

If fuel on the water has ignited, approach should be made from the direction where wind direction and velocity, water current, and site accessibility create an advantage. Fire can be moved away from an area by using a sweeping technique with hose streams. Foam and other extinguishing agents can be used where practical and necessary.

10-11.7

Scuba diving units should be dispatched to the scene of an aircraft accident in the water. Helicopters can be used to expedite the transportation of divers to the actual area of the accident.

All divers who might be called for this type of service should be qualified in both scuba diving and underwater search and recovery techniques.

10-11.8

In all operations where divers are in the water, standard diver's flags should be flown and all watercraft restricted from the diving area.

10-11.9

Victims in the water are more apt to be found downwind or downstream. Where only the approximate location of the impact site is known upon arrival, divers should use standard underwater search patterns marking the locations of major parts of the aircraft with marker buoys. If sufficient divers are not available, dragging operations should be conducted from surface craft. In no instance should dragging and diving operations be conducted simultaneously.

10-11.10

Life sustaining air can remain in large, submerged, occupied sections of the aircraft. As soon as practicable, entry by divers should be made carefully at the deepest point possible.

10-11.11

Where occupied sections of the aircraft are found floating, great care should be exercised not to disturb their buoyancy, and supplemental floating devices should be attached. Removal of any occupants should be accomplished as smoothly and quickly as possible. Any shift in weight or lapse in time can result in the section sinking. Rescuers should use caution so that they are not injured or trapped should the section capsize or sink.

10-11.12

A command post should be established on an adjacent shore to facilitate implementation of the airport/community emergency plan. (*See NFPA 424, Guide for Airport/Community Emergency Planning*.)

Chapter 11 Post-Aircraft Accident Procedures

11-1 General.

11-1.1

Many local statutes stipulate that it is the duty of the fire department to protect life and property from fire and to extinguish all destructive fires. They further state that no person has the right to interfere with or hinder the fire department in the performance of this responsibility. In aircraft accidents where the investigation of cause is very important, efforts consistent with the duty described above might involve moving parts and operating controls. When this must be done, ARFF personnel should be prepared to subsequently advise responsible authorities of the action they took.

11-1.2

If it is necessary to move portions of a damaged aircraft, either in rescue operations or fire control, caution should be taken to avoid changes in the aircraft's stability. Undue strain on the airframe can liberate fuel from damaged tanks, cause collapse or rollover of the fuselage, or cause greater injuries to trapped occupants.

11-1.3

During the course of the emergency, ARFF personnel should ensure that the “no smoking” rule is rigidly enforced at the scene of an aircraft accident and that all nonessential sources of ignition be prohibited in the immediate vicinity.

11-1.4

ARFF personnel should familiarize themselves with all regulations relating to movement of aircraft wreckage and disposition of accident fatalities. (*See also Appendix D*.)

11-2 Preservation of Evidence.

11-2.1

Following extrication of occupants from an aircraft, preservation of evidence at the site is of vital importance in determining the probable cause. ARFF personnel should be aware of this requirement, and it should be stressed in training exercises.

11-2.2

ARFF personnel should take notice of the condition and position of the aircraft structure prior to beginning any significant cutting or shifting of any portions of the wreckage. If time permits, a photographic record of initial conditions should be made for later study.

11-2.3

Any aircraft accident area should be roped off and perimeter security established to prevent the entry of unauthorized persons. Persons not actively engaged in operations should be denied entry into the area. Those persons inside the controlled area should be fully equipped with the necessary protective clothing and equipment to carry out their duties. (*See also 5-1.2*.)

11-3 Fatalities.

11-3.1

The location of all fatalities in and about the aircraft wreckage should be clearly identified by the use of a flag, stake, or other suitable marking and numbered to coincide with a number securely attached to the body, and photographed if possible. Triage/medical tags can be used for this purpose. (*See also NFPA 424, Guide for Airport/Community Emergency Planning*.)

11-3.2

Removal of fatalities remaining in an aircraft wreckage after the fire has been extinguished should be done only by, or under the direction of, the responsible medical examiner (coroner). Premature body removal can interfere with identification and destroy pathological evidence. If body removal is absolutely necessary to prevent further incineration, the original location and the body should be photographed, identified with a number, and the fact reported to investigators.

11-4 Preservation of Mail, Baggage, and Cargo.

11-4.1

The original location of mail sacks, baggage, and cargo should be observed and this information passed on to investigators. These items should be protected from further damage. If necessary, remove to a safe location such as the command post.

11-4.2

Postal officials normally extend blanket authority to fire departments to remove mail from aircraft involved in an accident for the purpose of saving as much of it as possible. After the responding postal official has been properly identified, the ARFF officer can transfer the custody of the mail.

11-4.3

If it is necessary to remove baggage from an aircraft involved in an accident, it should be placed in the custody of airline officials. Under certain circumstances, customs officials would be granted initial custody. Responsibility for final disposition of baggage belongs to the airline involved.

11-4.4

Cargo manifests should be reviewed for the presence of dangerous goods. If present, they should be examined for leaking containers. If leaks are found, contaminant and decontamination procedures should be initiated immediately by qualified personnel. If cargo is removed from the aircraft, it should be turned over to the responsible agency.

11-4.5

When personal property such as jewelry, purses, watches, etc., is found in the area of an aircraft accident, ARFF personnel should not move it but record the location and notify their commanding officer, who should advise security personnel of the information. These items and their locations can be of great value to the medical examiner in making positive body identifications.

11-5 Flight Data and Cockpit Voice Recorders.

Flight data and cockpit voice recorders are usually located in the aft fuselage area of most commercial aircraft. ARFF personnel should be able to recognize them so that they can be protected from loss or damage until accident investigators assume responsibility. Although no attempt should be made to remove these recorders from the aircraft, as they could be damaged by such efforts, if failure to remove them will result in their total loss, recovery should be made. (*See Figure 11-5*.)

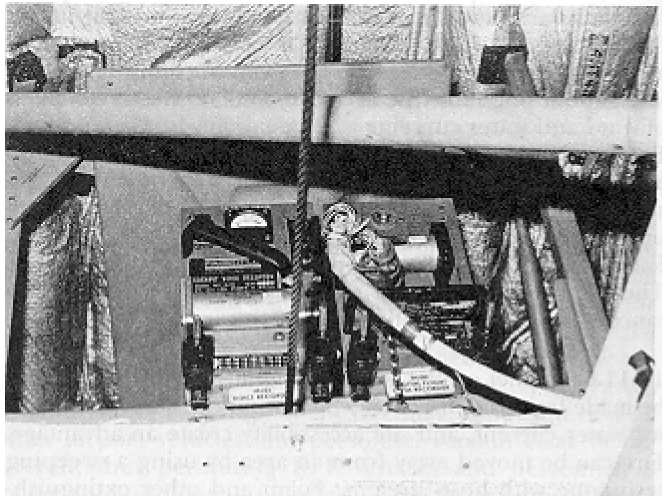


Figure 11-5 A flight data recorder (FDR) and a cockpit voice recorder (CVR) are shown mounted in an aircraft.

11-6 Defueling Accident Aircraft.

11-6.1

Defueling operations should be done under the direct supervision of a qualified aircraft fuel systems specialist. The defueling itself should be performed by qualified technicians using approved methods. (*See NFPA 407, Standard for Aircraft Fuel Servicing, and NFPA 410, Standard on Aircraft Maintenance*.) A standby fire watch should be provided by ARFF personnel during the entire defueling operation.

11-6.1.1 ARFF personnel should be made aware that the issue of defueling an inverted aircraft has very serious potential. The common conclusion of experts in this field is, "If there is no leakage, leave it alone until the rescue operation is completed." Remember that the issue here is defueling an inverted aircraft, not fuel leakage. If there is fuel leakage, it should be dealt with in the same manner as any other fuel leak, regardless of the aircraft's attitude.

11-6.1.2 There are a number of reasons why an inverted aircraft should not or cannot be defueled during the rescue operation:

(a) Ignition can be caused by surface generated static as the fuel flows between the aircraft fuel tank and the fueling vehicle;

(b) Due to the accident, fuel pump access doors and the fuel pumps themselves could have been damaged;

(c) The wing attitude could make it difficult to determine in which tank the fuel is located, in what position, and in what quantity, such that while attempting to defuel, the fuel could be accidentally discharged onto the accident site; and

(d) Fueling normally involves delivery by pressure, and defueling utilizes gravity flow from underwing orifices when the aircraft is on its wheels. Inverted aircraft or those on their bellies do not offer the benefits of gravity flow. This technical problem is compounded by the fact that most fueling vehicles cannot "lift" fuel by suction in the same way as fire vehicles "lift" water from a ground level reservoir up into their water tanks.

11-6.2

To control fuel system leaks prior to completion of aircraft defueling, fuel cell sealant, clay, or other material can be used to make minidams on smooth surfaces to direct the flow of fuel into containers. Crimping, pegs, and plugs should also be used where appropriate. It might also be possible to shovel trenches to direct the fuel to collecting spots where it can be protected from ignition sources.

11-6.3

During defueling operations, an ignition-free area with a radius of at least 50 ft (15 m) from the outer edge of the operating area should be maintained. Persons within the controlled area should be only those necessary for the work being done. Open flames, floodlights, ground power units, and radio transmitters should be prohibited in the operating area. ARFF personnel should also be aware that their vehicles and equipment can be a source of ignition and take necessary precautions.

11-6.4

Concurrent operations such as jacking, shifting, and removing panels should not be conducted during defueling operations. Transfer of fuel during defueling operations can cause changes in weight distribution, balance, and stability of the aircraft. Cribbing, blocking, use of air bags, and other stabilizing methods and equipment should be in place, ready for use if needed. Safe access for fueling vehicles, empty or full, should be provided.

11-6.5

Prior to moving, the interior of the aircraft wreckage should be well ventilated to remove all flammable vapors. After removal of the aircraft, ground surfaces should be thoroughly flushed of any flammable liquids or debris before permitting normal traffic to resume.

11-7 Aircraft Systems Hazards.

ARFF personnel should seek the advice of aircraft systems specialists concerning items that might present problems during overhaul and salvage operations. Advice can include information regarding liquid or pressurized systems that need to be bled off prior to any cutting, bending, or prying around components.

Chapter 12 Structural Fire Department Operations

12-1 General.

12-1.1

A prerequisite for the application of information contained in this chapter is a thorough review of the preceding chapters. Discussed are recommended procedures using apparatus, equipment, and resources available to most structural fire departments. Emphasis is placed on rescue of aircraft occupants.

Figure 12-1(a) On July 2, 1994, a DC-9 with 55 persons onboard collided with trees and a private residence near the Charlotte/Douglas International Airport, Charlotte, North Carolina. The tail section of the DC-9 is lodged in the carport of a house. The nose section is in the lower left. [*See Figure 12-1(b).*]

Figure 12-1(b) The nose of the DC-9 sheared off on impact with trees and skidded down a residential street.

12-1.2

Fire control is often the means by which rescue of aircraft occupants can be accomplished. Aircraft fuel fires require extinguishing agents and techniques common to Class B fires. Structural fire fighters therefore should be trained to effectively combat this type of fire utilizing available equipment and extinguishing agents. IT IS IMPERATIVE THAT FIRE DEPARTMENTS LOCATED NEAR AIRPORTS OR AIRCRAFT FLIGHT PATHS BE THOROUGHLY FAMILIAR WITH THE RECOMMENDATIONS SET FORTH IN THIS GUIDE.

12-1.3

The recommendations presented in this chapter should not be interpreted as an alternative for adequate airport-based rescue and fire fighting services as outlined in NFPA 403, *Standard for Aircraft Rescue and Fire Fighting Services at Airports*.

12-2 Pre-Incident Planning and Training.

12-2.1

Fire departments located near airports should make appropriate arrangements to participate in the airport/community emergency plan. The fire department's services should also be made available to the airport during any special events such as air shows or during periods of unusually heavy aircraft traffic. Since no community is immune to an aircraft accident, all fire departments should implement pre-incident planning and training for this type of incident.

12-2.2

At an aircraft accident, teamwork is so important that fire department officers should review pre-incident planning as the one absolutely indispensable element in aircraft rescue and fire fighting.

12-2.3

The psychological factors involved in aircraft rescue and fire fighting can be successfully overcome only by realistic pre-incident planning and training. Consideration should be given to conducting a critical incident stress debriefing for responding personnel. Each fire department should conduct realistic simulated aircraft fire drills using the types of extinguishing agents and equipment they expect to have available. One important training objective should be to learn the capabilities and limitations of the department's pre-incident plan procedures.

12-2.4

Live fire training is essential in maintaining qualified and certified fire fighters. Traditionally, hydrocarbon fuel from various sources has been the fuel of choice used to conduct this training. However, with stricter environmental laws and improved technology, propane live fire simulators are in use and fulfilling training needs of the fire fighter. The size of the mock-up should come as closely as possible to that of the aircraft utilizing the facility. Training should include interior, engine, wheel brake, exterior pool fire, running fuel, and three-dimensional scenarios. The propane-fired simulator should be equipped with the necessary automatic features to maximize fire fighter safety.

12-2.4.1 An aggressive attack using hose lines with spray nozzles, employing pre-incident planned operating techniques, can develop the confidence necessary to handle these types of incidents successfully.

12-2.5

The volume of smoke, fire, and intense heat accompanying an aircraft fire can appear to be an overwhelming situation to untrained fire fighters. They might be reluctant to attack and control the fire with a limited water supply and conventional equipment for the amount of time required to complete rescue operations. Experience has proven that rescues can be accomplished even where large quantities of spilled aircraft fuel are burning.

12-2.6

Training coordination between military, civil airport, and structural fire departments is strongly recommended. Execution of mutual aid agreements between these agencies will help ensure well-coordinated plans for rescue and fire fighting. In the United States and Canada, military air base commanders are urged to make their training facilities available to nearby fire departments, particularly where those departments are likely to be called upon to assist in rescue and fire fighting operations.

12-2.7

Structural fire department personnel should be thoroughly familiar with the most efficient response routes to the airport and the surrounding area. They should know all the airport's accesses and entrances and be familiar with all rules governing the operational area. They should also be provided with any necessary keys or gate codes. As a minimum, their training should include information relative to items (a) through (j) in 2-3.4 of this guide.

12-2.8

Aircraft familiarization is also an important part of aircraft rescue and fire fighting pre-incident planning. Structural fire departments should contact the airport fire department to arrange qualified persons to take fire fighters through the various aircraft using the airport. When inspecting the aircraft, the following facts should be noted: location of fuel, hydraulic oil, lubricating oils, and other storage locations and capacities; seating arrangements; and emergency exits and hatches and how they can be opened. Also important are the locations of batteries, oxygen storage, and various system shutoffs. (*See also 2-3.3*.)

12-2.9

Fire departments should avail themselves of informational charts of all aircraft types using the airport. Airlines and aircraft manufacturers can provide these charts, which depict most information pertinent to rescue and fire fighting operations. (*See also examples of charts in NFPA Aircraft Familiarization Charts Manual*.)

12-3 Aircraft Accident Operations.

12-3.1

When fire departments receive a report that an aircraft is experiencing an in-flight emergency or that it is down in the vicinity, they should immediately alert the fire forces that could be affected. Fire and police units should coordinate their efforts. Making use of a police helicopter, if available, could help coordinate operations and serve as a communication link between the fire units and the control tower.

12-3.2

Size-up (risk assessment) begins with the fire department's first notification of an incident. Multiple calls from various sources in the vicinity of the airport should alert fire dispatchers of a possible major aircraft accident and warrant an immediate first alarm response. A multiple unit response would ensure arrival at the scene of at least one unit despite the likelihood of blocked access due to debris and traffic. During the initial response, pre-incident plans should be activated, and all pertinent information should be transmitted to the responding units.

12-3.3

The following factors are among those that are important to the size-up (risk assessment) process:

(a) Occupant survival is generally limited to accidents where the fuselage is not severely broken up and a fire has not yet developed.

(b) Environmental and geographical factors have a major impact on response capability. An accident in a wooded area during a winter snowstorm presents different problems than a similar accident on a clear summer afternoon.

(c) Time of day is a factor. An aircraft accident that occurs in a shopping center parking lot has a different life hazard potential at 4:00 a.m. on Sunday than a similar event at 4:00 p.m. on Friday.

(d) The magnitude and nature of the aircraft accident need to be considered. An aircraft accident in an open field can set off a major grass or brush fire, but an accident in a populated area can be more complex. If structures are involved, their occupancy, construction type, and stability need to be evaluated. In addition, an assessment of damage to public utilities and their possible effect on operations should be made. Because of the possibility that water supply from hydrants might not be available due to system damage, it is good practice to include water tanks in the first response.

(e) The nature of the aircraft operation at the time of the accident is of importance. If a crop-dusting aircraft accident occurs, steps need to be taken to protect emergency personnel and limit the spread of pesticide contamination.

(f) Aircraft accidents that occur on takeoff usually involve large amounts of fuel. In addition to the fire problem that could evolve, steps need to be taken to prevent a fire, or fuel or fuel vapors from entering waterways, streets, and underground facilities.

12-4 Basic Fire Control.

12-4.1

Specific implementation of basic aircraft fire control methods should depend upon the fire fighting equipment and types of extinguishing agents available to individual fire departments.

12-4.2

Always assume that there are survivors of an aircraft accident until it is confirmed otherwise. In some instances, however, rescue of occupants cannot be accomplished because of the remoteness of the accident or the severity of the impact forces. In such instances fire fighters should make a thorough search for survivors, protect any exposures, attack and extinguish the fire, and preserve the scene until the proper authorities arrive to assume responsibility.

12-4.3

Fire fighters should have knowledge that aircraft construction differs from most other structures in ways that make fires more dangerous for the occupants and for themselves. Aircraft occupants are enclosed in a thin shell and are surrounded by large amounts of fuel with tremendous heat potential. Large aircraft have hollow wall construction with the void filled with blanket-type insulation. Fire walls and draft stops are nonexistent except for engine, galley, and cargo bay areas. These deterrents to fire spread are not comparable to fire barriers found in building construction.

12-4.4

In all large aircraft and in many smaller models, plumbing, electrical, heating, and cooling services are provided. Consequently there are aircraft equivalents of pipe chases, electrical load centers, buss bars, etc. The aircraft electrical system should be treated with the same safety precautions as those used for a typical residence.

12-4.5

Most aircraft contain pressure hydraulic reservoirs and liquid or gaseous oxygen lines constructed mostly of aluminum. These, as well as brake lines, will rupture quickly under fire conditions. Fuel tanks are interconnected, and fire can propagate through ventilation ducts or manifolds. Fire impingement on empty or near empty fuel spaces often results in a violent rupture of tanks and wings.

12-4.6

Aircraft also differ from other structures in the critical aspect of stability. Most structures are cubical in shape and will collapse in place. Aircraft are cylindrical, conical, and usually on wheels. Therefore, movement, such as tilting and rotation effects, should be considered. Guy lines, chocks, air bags, and cribbing should be required when working around damaged aircraft. Current modern aircraft can weigh 800,000 lb (363,200 kg) or more and have a height greater than a five-story building.

12-4.6.1 Experience has shown that cribbing and shoring material should be unpainted to avoid the inherent slipperiness of painted surfaces when wet and should be made of hard wood so as not to be easily compressed. It should be available and included as a resource in the airport's emergency preparedness plan. It should be of appropriate thickness and length to accommodate the largest aircraft scheduled into the airport. Aircraft recovery manuals should be used to ascertain appropriate cribbing sizes.

12-4.6.2 It should be noted that the training of ARFF personnel to shore unstable aircraft wreckage to facilitate rescue implies the provision of suitable materials. To be effective these materials must be constantly available for immediate deployment. To achieve this, the materials should be stored either in a palletized form (requiring ready access to appropriate lifting and transport equipment) or on a dedicated vehicle, such as a trailer. In either case, a designated responder should be capable of deploying these supplies at all times, under all conditions of weather, visibility, and adverse terrain.

12-4.6.3 As an alternative to the logistics of cribbing, consideration might also be given to the deployment of earth-moving or similar heavy-duty lifting equipment, designed for off-road performance and having the weight and flexibility of electrohydraulics to support or suspend any unstable elements of a damaged aircraft. Skilled operators should also be readily available if this type of equipment is to be used at an aircraft accident site.

12-4.6.4 Regardless of the method or equipment chosen for raising, shoring, or moving a damaged aircraft, the same requirement for guidance based on aircraft structural knowledge is required. It is important to understand that imposing loads at unsuitable locations on the aircraft could merely exacerbate the situation, promoting, rather than preventing, further disruption of the wreckage. It is advantageous for the task to be performed under the supervision of aircraft maintenance personnel, preferably those familiar with the specific type and model of aircraft involved.

12-5 Accidents without Fire.

12-5.1

When an aircraft accident occurs without fire, the following fire prevention procedures should be initiated. Hose lines should always be laid out and charged. Any spilled fuel should be covered with foam. Ignition sources such as hot aircraft components or energized electrical circuits should be eliminated. When moving wreckage, care should be taken to avoid causing sparks.

12-5.2

When foam is not available, water spray can be used to cool hot aircraft components and to move fuel away from the fuselage. However, washing fuel away with water requires that special attention be given to exposures, low areas, and drains where fuel and vapors can flow. The fuel should be directed to an area of containment free from ignition sources where it can later be safely removed.

12-6 Accidents with Fire.

12-6.1

The location of survivors and the sources of heat or flame impingement against the aircraft will determine where hose streams should be applied first. Fire fighters should keep in mind that the heat input into the occupied portion will be reduced if the surfaces of the fuselage exposed to flame or heat can be kept wet. If the fire has penetrated the fuselage, a direct internal attack should be initiated. Care should be taken to see that water runoff does not cause the fire to spread.

12-6.2

Normally, hose streams should be directed along the fuselage and efforts concentrated on driving the flames outward, allowing occupants to escape and permitting entry by fire fighters for rescue operations. The fuselage and fuel tank areas should be kept cool. It might be necessary to create an escape path from an exit point by “sweeping” fire out of the area with spray streams. Once an escape path has been established, it should be maintained for evacuating occupants and fire fighters performing rescue.

12-6.3

All available hose lines should attack the fire from the same general direction. If crews are operating on opposite sides of the fuselage, they should be cautious not to push the fire toward each other. Because prompt action is necessary to effect rescue, the first hose line in operation should be advanced immediately to keep the fuselage cool.

12-6.4

For aircraft rescue and fire fighting, there are too many variables to establish hard and fast rules regarding use of equipment. Spray streams are normally more effective than straight streams in applying water or foam and afford much more personal protection.

12-6.5

The number of handlines will be determined by the availability of the water, equipment, and personnel. Immediately upon arrival, all deployed hose lines should be charged regardless of the fire situation. This cannot be overemphasized.

12-7 Fire Fighting with Water.

12-7.1

If an aircraft accident occurs in a remote area with limited water available on responding apparatus, a supplemental source of water should be established. The use of tank vehicles to shuttle water between the nearest water source and the accident site should be considered.

12-7.2

When using water to combat flammable liquid fires, spray nozzles, operating at approximately 100 psi (689 kPa), should be used. Spray patterns, on initial approach to the fire, should be set at a wide angle momentarily to reduce the heat and flame and then reduced to 30 degrees to attack the fire. The best technique is to sweep the flame off the surface of the fuel by maintaining the lower portion of the spray pattern at the lowest level of the flame. This action also tends to cool the fuel surface and reduce vaporization. However, because there is no vapor seal provided, as when foam is used, chances for reignition remain, and fire fighters should take the necessary precautions to prevent this occurrence (*see Section 12-5*). Additional hose lines, used exclusively for the protection of rescue and fire fighting personnel, are encouraged.

12-7.3

Runoff from water streams can cause the spread of fire to exposures. Straight streams should be used when the heat is too intense to approach initially with spray streams or when the objective is to wash the burning liquid away from the fuselage to an area where there is no exposure.

12-7.4

Trained fire fighters employing proper operating techniques can accomplish a successful rescue operation at an aircraft accident with a limited amount of water if all efforts concentrate on establishing a fire-free evacuation path. Efforts to save the aircraft hull or exposures might have to be delayed until additional resources arrive.

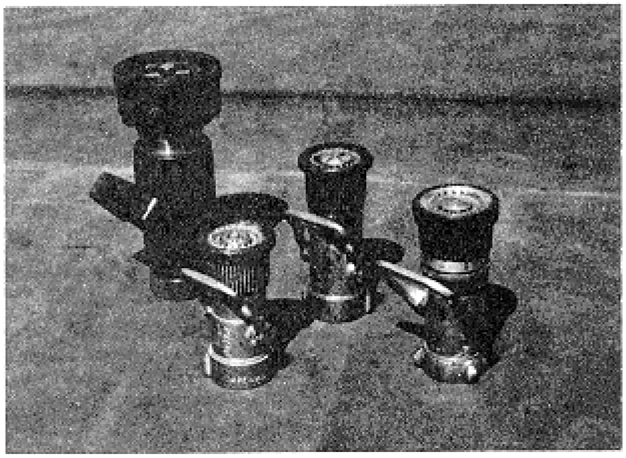


Figure 12-7 Photo shows a variety of typical spray nozzles currently used by structural fire departments. All have the feature of adjustable spray patterns and straight stream settings. Some also have variable flow settings. Most fire chiefs agree that a nozzle setting of 30 degrees provides the best pattern for fighting flammable liquid fires with either water, AFFF, or FFFP solutions.

12-7.5

Addition of a wetting agent might increase the effectiveness of available water; however, certain wet water additives can destroy some foams. Compatibility of the agents should be checked prior to their use.

12-7.6

Approved portable dry chemical, foam, or halon extinguishers can be used to supplement the primary attack with hose streams. These agents are particularly effective on localized fires or in areas that cannot be readily reached by hose streams. In some instances, bulk supplies of dry chemical, foam, or halon are made available to fire departments on an emergency basis. This resource should be considered when pre-incident planning for aircraft accidents.

12-7.7

The technique of using multiple spray nozzles with overlapping 30-degree patterns creates a continuous curtain of water spray. They should be advanced directly to the aircraft, parallel to the fuselage from either the nose or tail section, dependent on wind direction. This procedure will open an area for evacuation and rescue. If possible, hose lines should be advanced with the wind at the fire fighters' backs, as greater reach is possible with the spray streams and less heat is experienced. Progress and stream effectiveness can be monitored more easily from upwind with the smoke moving away. If there is an adequate water supply, a large spray nozzle attached to a deck gun or a portable deluge set can be used to keep the fuselage and fuel tank areas cool.

12-7.8

Protection of exposed property should be considered whether fire exists or not. In addition to structures, exposure protection plans should include drains, sewers, waterways, power lines, and other properties where a flowing fire or unignited fuel could cause fire extension or contamination. Public utility authorities should be notified of any involvement affecting facilities under their control. Master streams from deluge sets, deck guns, or ladder pipes can be used to protect exposures if water supplies are adequate.

12-8 Fire Fighting Foam.

12-8.1

Aqueous film forming foam (AFFF), film forming fluoroprotein foam (FFFP), or protein foam concentrates properly proportioned into fresh water are more effective than just water on flammable liquid fires.

12-8.2

Techniques for the application of foam vary with the type used. Protein and fluoroprotein foam solutions should be applied with an aspirating foam nozzle at a pressure of 100 psi (689 kPa). A constant flow from the nozzle should be maintained to ensure an even pickup of the concentrate. The proper operating pressure should be maintained during the entire foam application for effective results. AFFF and FFFP can be applied using either an aspirating foam nozzle or a conventional spray nozzle operating at 100 psi (689 kPa).

12-8.3

A foam/water solution using protein, fluoroprotein, or AFFF can be made up in the water tank of a structural fire fighting apparatus for direct foam application through hose lines equipped with appropriate nozzles. After draining the appropriate amount of water from the tank, add the required amount of foam-liquid concentrate. Mix the solution by opening the “tank to pump” valve and place the pump in gear; open the “tank fill” valve slightly, and circulate the solution through the pump and tank to assure a good mix. After use, any unused solution should be drained and the entire water system should be well flushed before refilling the water tank for regular use.

12-8.4

Some fire departments have purchased combined agent vehicles for special purposes, such as vehicle accidents and flammable liquid spills. Such combined agent vehicles are a valuable tool for the initial response to an aircraft accident.

12-9 Vehicles.

Fire fighting apparatus designed and intended for use on paved surfaces should not be used for cross-country travel. Extended hose lines from a position on a hard road surface should be used rather than risking immobilization. Once a vehicle has become immobilized, it could not be moved if it became endangered by a developing fire situation. It can also block or delay other emergency vehicles responding to the site.

12-10 Post-Accident Procedures.

Fire department personnel should be familiar with the information contained in Chapter 11 and Appendix D of this guide.

Chapter 13 Referenced Publications

13-1

The following documents or portions thereof are referenced within this guide and should be considered part of the recommendations of this document. The edition indicated for each reference is the current edition as of the date of the NFPA issuance of this document.

13-1.1 NFPA Publications.

National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.

NFPA 403, *Standard for Aircraft Rescue and Fire Fighting Services at Airports*, 1993 edition.

NFPA 407, *Standard for Aircraft Fuel Servicing*, 1996 edition.

NFPA 410, *Standard on Aircraft Maintenance*, 1994 edition.

NFPA 414, *Standard for Aircraft Rescue and Fire Fighting Vehicles*, 1995 edition.

NFPA 424, *Guide for Airport/Community Emergency Planning*, 1996 edition.

NFPA 1003, *Standard for Airport Fire Fighter Professional Qualifications*, 1994 edition.

NFPA *Aircraft Familiarization Charts Manual*, 1996.

13-1.2 Other Publications.

13-1.2.1 ICAO Publications. International standards and recommended practices are promulgated by the International Civil Aviation Organization, 1000 Sherbrooke Street West, Montreal, Quebec, Canada H3A-2R2.

Airport Services Manual, Part 7: "Airport Emergency Planning," first edition, 1980.

13-1.2.2 Research and Special Programs Administration Materials Transportation Bureau. Request for single free copy for emergency service organizations may be addressed to: U.S. Department of Transportation, Materials Transportation Bureau, Attention: DMT-11, Washington, DC 20590.

Guidebook for Hazardous Materials Incidents (1984 Emergency Response Guidebook), DOT P 5800.3.

Appendix A Air Transport of Dangerous Goods (Hazardous Materials and Restricted

Articles) and Nuclear Weapons

This Appendix is not a part of the recommendations of this NFPA document but is included for informational purposes only.

A-1 Commercial Air Transport of Dangerous Goods. The carriage in commercial transport aircraft of dangerous goods is an accepted practice and is closely controlled by national and international regulations.

A-1.1 Definition of Dangerous Goods.

(a) Dangerous goods include explosives and any other article defined as a Combustible Liquid, Corrosive Material, Infectious Substance, Flammable Compressed Gas, Flammable Liquid, Flammable Solid, Magnetized Material, Nonflammable Compressed Gas, Oxidizing Material, Poisonous Article, Radioactive Material, and other restricted articles.

(b) Some unlikely items can come under the heading of dangerous goods; for example, wheel chairs could contain wet-cell batteries, while breathing apparatus might have compressed air cylinders. It is well to be aware of hazards that might not be immediately apparent.

A-2 Radioactive Material. Radioactive materials constitute a particular hazard. They emit certain rays that can be a health hazard and that cannot be detected except by instruments. Radioactive materials transported by air fall into three categories:

(a) Category I — Material emits minimal radiation;

(b) Category II — Emits more radiation and is assigned a transport index up to 1;

(c) Category III — Could have a transport index of 1.1, up to a maximum of 10.

A-3 Transport Index.

A-3.1 The transport index for a package of radioactive material is a simplified expression of the maximum amount of radiation emitted, in millirem per hour, measured one meter from the surface of the package; this number should appear on the notification and such notification received by the pilot-in-command. The sum of the transport indexes is the primary concern, along with the stowage of the packages, to ensure that no living beings are exposed to hazardous radiation.

NOTE 1: In the United States, dangerous goods are transported by air, under authority of the *Code of Federal Regulations*, Title 49, "Transportation," Part 175, published by the Office of the Federal Register National Archives and Records Service, General Services Administration, Washington, DC 20408.

NOTE 2: The International Air Transport Association has issued the IATA *Restricted Articles Regulations*, which is available from IATA Headquarters, Montreal, Canada. Also, the International Civil Aviation Organization has developed technical instructions for the safe transportation of dangerous goods by air (document 9284-AN/905) available from ICAO, 1000 Sherbrooke Street West, Montreal, Quebec, Canada, H3A 2R2.

A-3.2 Dangerous goods are regularly being carried on commercial transport aircraft. This includes passenger aircraft, passenger cargo aircraft (COMBI), and cargo aircraft. While the packaging requirements used to transport these materials are designed for proper containment, the possibility of breakage cannot be overlooked. This introduces the hazards of leaking flammable liquids and poisons, or radioactive contamination at an accident site. By knowing and recognizing dangerous goods labels, fire fighters can be alerted to these hazards.

A-4 Dangerous Goods Warning Labels.

A-4.1 The following dangerous goods warning labels are authorized by the U.S. Department of Transportation based on the United Nations labeling system and are authorized for domestic and foreign shipments. Shippers must furnish and attach an appropriate label(s) to each package of dangerous goods being offered for shipment by air. If the material in a package has more than one danger classification, one of which is Class A poison, or radioactive materials, the package must be labeled for each danger. When two or more dangerous goods of different classes are packed within the same packaging or outer enclosure, the outside of the package must be labeled for each material involved. Radioactive materials requiring labeling must be labeled on two opposite sides of the package and indicate the transport index.

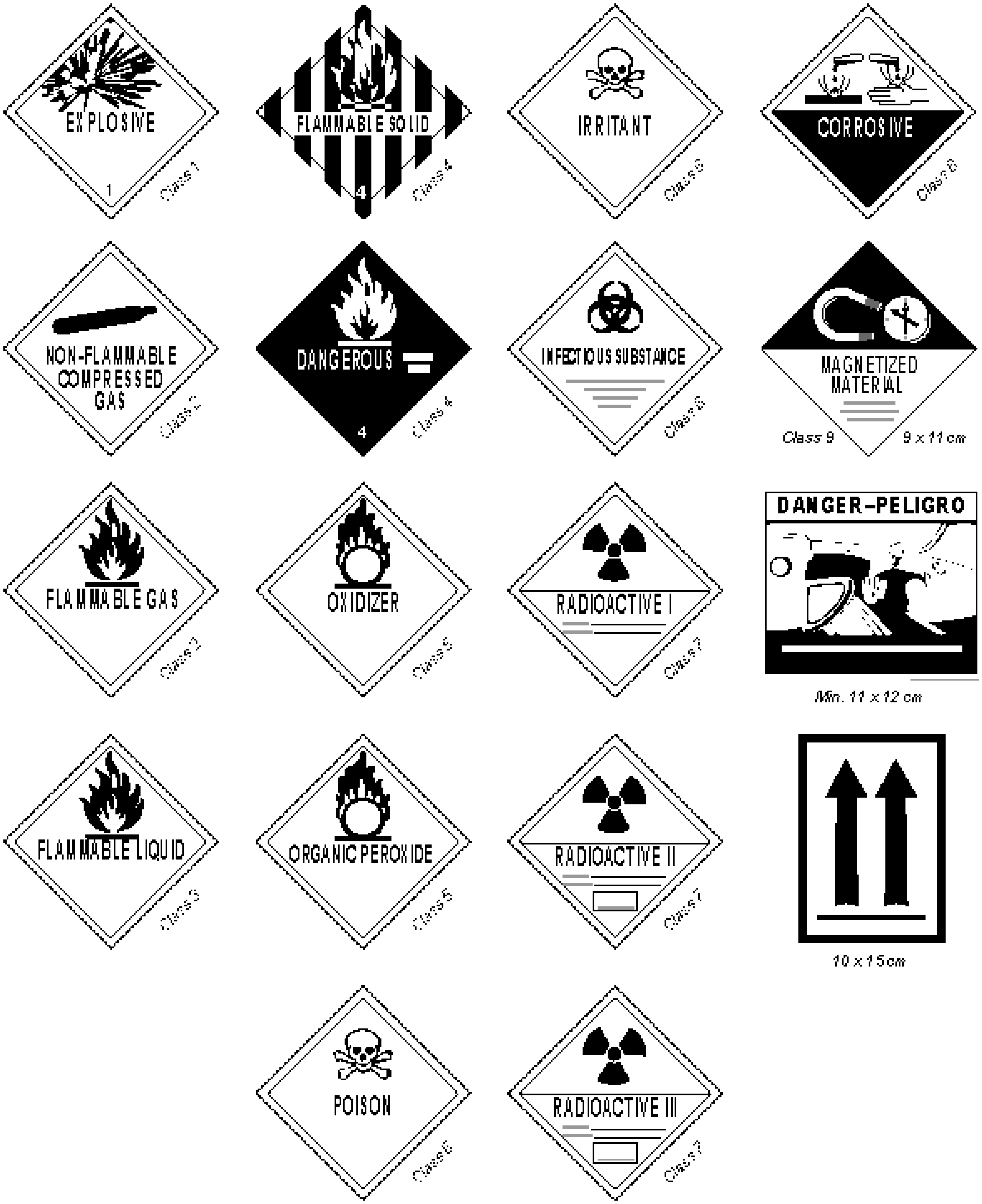


Figure A-1 Warning labels.

Dangerous Goods Class Numbers. Dangerous goods are classified by the UN, ICAO, IATA, and the U.S. DOT as follows:

Class 1	Explosives
Class 2	Gases: compressed, liquefied, dissolved under pressure, or deeply refrigerated
Class 3	Flammable liquids
Class 4	Flammable solids: substances susceptible to spontaneous combustion; substances that, on contact with water, emit flammable gases.
Class 5	Oxidizing substances: organic peroxides
Class 6	Poisonous (toxic) and infectious substances
Class 7	Radioactive materials
Class 8	Corrosives
Class 9	Miscellaneous dangerous goods (including magnetized materials, articles liable to damage aircraft structures, and articles possessing other inherent characteristics that make them unsuitable for air carriage unless properly prepared for shipment).

The bottom half of the DOT diamond-shaped labels can be printed in the language of the country of origin.

A-4.2 The pilot in command of an aircraft should be provided with all relevant information regarding dangerous goods on board the aircraft, and, in the event of an incident, this information should be obtained by airport emergency services either directly from the pilot or through the operations office.

A-4.3 The NFPA publication, *Fire Protection Guide on Hazardous Materials*, provides essential information for those confronted with emergencies such as fire, accidental spills, and aircraft accidents. With the urgency of prompt identification in mind, this guide has been arranged so that the user can get to the information with a minimum of delay.

A-5 Incidents or Accidents Involving Radioactive Materials.

A-5.1 Radioactive materials carried in commercial transport aircraft are packed in rugged containers of varying sizes, such as steel drums, wooden containers, heavy corrugated cardboard, or lead boxes. In the event of an aircraft accident, the possibility of these containers breaking should always be considered.

A-5.2 This introduces the hazard of radioactive contamination of an accident site. The following procedures should then be followed in the United States (similar procedures are followed in other countries):

(a) Notify the nearest Department of Energy office or military base (if military aircraft is involved) of the accident immediately. They in turn will respond with a radiological team to the accident scene.

(b) Restrict the public to as far from the scene as possible. Souvenir collectors should be forbidden in all accidents.

(c) Segregate fire fighters who have had possible contact with radioactive material until they have been examined further by competent authorities.

(d) Remove injured from the area of the accident with as little physical contact as possible and hold them at a transfer point. Take any measure necessary to save lives, but carry out minimal (no more than necessary) first aid and surgical procedures until help is obtained from the radiological team physicians or other physicians familiar with radiation medicine. Whenever recommended by a doctor, an injured individual should be removed to a hospital or office for treatment, but the doctor or hospital should be informed when there is reason to suspect that the injured individual's body or clothing has been contaminated with radiation.

(e) In accidents involving fire, fight fires upwind as far as possible, keeping out of any smoke, fumes, or dust arising from the accident. Handle this as a fire involving toxic chemicals (using positive pressure self-contained breathing apparatus and full protective clothing). Do not handle suspected material until it has been monitored and released by monitoring personnel. Segregate all clothing and tools used at the fire until they can be checked by the radiological emergency team.

(f) Do not eat, drink, or smoke in the area. Do not use food or drinking water that might have been in contact with material from the accident.

(g) The use of instruments such as Geiger counters, ionization chambers, dosimeters, etc., is the only accurate means of determining if radioactive contamination is being given off.

(h) To the extent possible, runoff water and other agents used in fire fighting and cleaning should be channeled, collected, and dammed to prevent entry into water courses and the possible spread of contamination.

A-6 Military Aircraft Carrying Nuclear Weapons.

A-6.1 While most military aircraft will attempt to return to a military airbase in case of emergency, this is sometimes impossible, and landings are frequently made at nonmilitary airports. There are also many cases where "joint-use" airports serve both the military and civil aircraft operations. For these reasons it is advisable for aircraft rescue and fire fighting crews to be familiar with the various types of military aircraft operating in the area. For this purpose, training visits to promote knowledge of the special features of military aircraft at nearby military installations are of value. Such liaison is encouraged by the military.

A-6.2 Any person receiving information of a military aircraft accident should immediately notify the base operations office at the nearest military establishment giving all relevant information. Telephone numbers of such military installations should be kept on hand at civil airports, nearby municipal fire stations, and in airport control towers.

A-6.3 Care should be exercised by the rescue and fire fighting crews when approaching any military aircraft involved in fire. Armament, ejection seats, or hazardous or other dangerous cargoes can present severe hazards during such operation.

A-6.4 The possibility of an atomic explosion from the detonation of a nuclear weapon or warhead involved in a fire, inadvertent release, or impact accident is so small it is practically nonexistent. Safety features and devices have been carefully designed and incorporated in nuclear weapons and warheads to make this assurance possible. The danger of a nuclear weapon is from the high explosives (HE) used plus radiation from the components.

A-6.5 The presence of nuclear weapons in aircraft generally creates no greater hazard than does the presence of conventional high explosives. Most weapons contain a high explosive that could detonate upon moderate to severe impact or when subject to fire. In fact, exposure to heat can make the high explosive more sensitive. In nuclear weapons, the amount of high explosive is considerably less than that found in conventional high explosive bombs. Chemical or radiological hazard might exist during and after an accident or in a fire where a nuclear weapon is involved.

A-6.6 Basically, the same techniques are used for fighting aircraft fires involving nuclear weapons as are those in which conventional high explosive bombs are involved; special extinguishing agents are not required to control and extinguish such fires. The brief amount of time available to control or extinguish the fire before an explosion might be expected is the only special factor to be considered.

A-7 Description. In general, nuclear weapons resemble conventional bombs in that they are enclosed in a shell or casing that is generally cylindrical in shape with tail fins. The weapon or warhead casings are of various thicknesses and might break up upon impact. Most weapons contain a conventional type of high explosive that can detonate upon moderate to severe impact or when subject to fire. The quantity of high explosives involved in a detonation can vary from a small amount to several hundred pounds and constitutes the major hazard in such an accident. If the casing breaks upon impact, the exposed and unconfined pieces of high explosive can ignite and burn or might explode if stepped on or run over. Some minor radiological hazards might exist regardless of the type of weapon, if the weapon burns or if detonation of a high explosive occurs.

A-8 Time Factors. The length of time available to safely fight a fire involving nuclear weapons depends largely upon the physical characteristics of the weapon or warhead case, the intensity of the fire, and the proximity of the fire. Since weapon and warhead cases vary in thickness, fire fighting time factors range from 3 minutes to an indefinite period if the fire impact incident does not detonate the high explosive immediately. The time element for each type of nuclear weapon or component is an important factor in fighting these fires. As soon as fire envelops the weapon area these time factors become effective. For weapons or warheads within a fire impact incident area, and subject to extreme heat but not enveloped in flames, a time factor of 15 minutes will apply; if the fire fighting time factor is unknown to the fire fighters, the minimum time factor of 3 minutes should be observed. Military flight communications procedures normally provide for notification to control towers of pertinent information regarding such time factors. When a weapon or warhead has been involved in a fire and its time factor has expired, even though the fire has been extinguished or burned out, safe evacuation distances should be observed until the arrival of authorized explosive ordinance disposal personnel.

A-9 High Explosive Blast and Fragmentation. The radius of a high explosive blast from a weapon varies, depending on the amount of high explosive that actually detonates. High explosive blast fragmentation distances for these weapons range from a minimum radius of 400 ft (122 m) to a maximum of 1000 ft (305 m). Personnel within these areas can be seriously injured from blast or fragmentation upon detonation of the high explosive. These areas and distances should be considered during the initial fire department approach to an accident where weapons have been enveloped in flames for a period approximating or exceeding the weapon time factor limitations. All except experienced fire fighting personnel should immediately evacuate to a minimum distance of 1500 ft (450 m) for protection against blast or fragmentation.

A-10 Precautionary Measures. Under no circumstances should any high explosive material from ruptured weapons that have been exposed to fire (or any components that have been scattered) be handled, stepped on, driven over, or disturbed in any manner. This material is extremely sensitive to minor detonations from shock or impact and can cause serious injury. Protective clothing and positive pressure self-contained breathing apparatus should be worn during fire fighting operations to provide the fire fighter maximum protection from any chemical or minor radiological hazards that are present. Additional protection is afforded by fighting any fire from an upwind position. All exposed clothing, apparatus, and equipment used during a fire or impact incident where nuclear weapons or components have been involved should be monitored for possible radiological contamination by specialized recovery personnel equipped for this purpose.

A-11 Associated Hazards.

(a) *Radiological.* In the event of a high explosive detonation or burning of a weapon, one has to be concerned principally with Alpha-emitting contamination, which is serious only when ingested. Other types of radiation, which are harmless at the low levels produced in a weapon, can be detected with the use of sensitive detection instruments. (The effect of this radiation can be likened to the effects of radiation emanating from a luminous dial wristwatch.) Since Alpha-emitting particles are so fine that they can be carried as smoke or dust from the burning or high explosive detonation of a nuclear weapon, some Alpha-emitting contamination should be expected in the immediate accident area and downwind. Although this material can present a minor radiation problem, danger from these particles exists only when they are inhaled in significant amounts. Protection against the highest Alpha levels that could be expected from such burning or high explosive detonation incidents is afforded fire fighting personnel by the prescribed protective clothing and self-contained breathing apparatus.

(b) *Fire.* Hazards associated with the burning of nuclear weapons and components are generally the same as those presented by conventional high explosives.

(c) *Impact.* Weapons or warheads can break up, and the high explosive can detonate from impact. Detonation and breakup are contingent to a large degree upon the characteristics of the weapon or warhead case, the impact velocity, and the location of aircraft suspension devices.

(d) *Sympathetic Detonation.* Detonation of a weapon or warhead, by fire or by impact, is also likely to induce detonation (nonnuclear) of any other weapon or warhead in the open within a 50 ft to 300 ft (15 m to 90 m) radius of the incident area.

(e) *High Explosive Burning Characteristics.* Flame and smoke characteristics of burning high explosives vary and provide no specific pattern upon which to determine when the high explosive is about to detonate. Burning high explosives produce flames of various colors; they can be bright red, yellow, greenish-white, or combinations of no predominant color. Some give off a white smoke, while others burn with no trace of smoke.

Appendix B Specialized Vehicles and Equipment

This Appendix is not a part of the recommendations of this NFPA document but is included for informational purposes only.

B-1 Hovercraft. The Hovercraft in Figure B-1 is typical of many designs available. They are easily operated and maintained with minimum training and can traverse a variety of surfaces such as water, tidal flats, snow, and ice. Payloads of 2000 lb (908 kg) permit up to 20 life rafts to be carried on this model. Piston engine operation offers a unique rescue vehicle at a fraction of the cost of a helicopter.

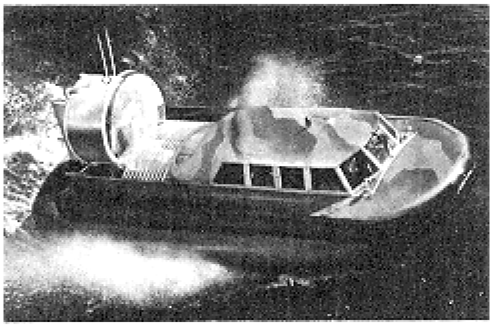


Figure B-1 Hovercraft.

B-2 Elevated Platform. Elevated platform vehicles can provide valuable assistance when emergencies involve “wide-body” style aircraft. When fires occur in the tail section engine of this type of aircraft, fire fighters can be positioned to permit proper application of extinguishing agent on the fire.

Figure B-2 Elevated platform vehicle.

Appendix C Driver's Enhanced Vision System: A Technical Approach for Aircraft Rescue and Fire Fighting Services

This Appendix is not a part of the requirements of this NFPA document but is included for informational purposes only.

C-1 Introduction. Several accidents have occurred in poor visibility conditions, and, with the proliferation of category IIIC landing systems, more requirements for fire fighting in low visibility conditions can be expected. Aircraft rescue and fire fighting services currently have no reliable way to locate and navigate crash sites at airports under conditions of poor visibility.

C-2 Background. Aircraft rescue and fire fighting services are required to demonstrate an ability to respond anywhere on the airport operational runway areas as part of earning their annual certificate. This response requirement is considered vital to the ability of ARFF services to gain control of a rapidly growing external post-crash fuel fire and their ability to protect the evacuating passengers from the aircraft fuselage. A response in 3 minutes is dependent on the vehicle's ability to accelerate rapidly from the rescue service's facilities and to maintain approximately a 50-mph (80.5-km/h) approach to the accident site. Accomplishing this task under substandard visibility conditions such as fog and rain prevents the responding vehicles from reaching this speed.

There is a clear need to provide operational equipment in the rescue vehicles that maintains their response ability if low visibility flight operations are to be conducted.

The problem of poor visibility response at airports for rescue and fire fighting services can be broken down into three components:

(a) Locating the accident sites;

(b) Navigating aircraft rescue and fire fighting vehicles to crash sites;

(c) Negotiating terrain and obstacles in low visibility conditions.

Airport fire services need a driver's enhanced vision system (DEVS) that addresses these three components.

Aircraft rescue and fire fighting services should obtain an accurate position fix on the crash site within a time parameter that is comparable to their response time (under 3 minutes). The current system for locating crash sites that are not visible to aircraft rescue and fire fighting services relies on visual observations, estimates, and verbal descriptions of airport landmarks provided by air traffic controllers. This system is prone to human error. The optimal solution to this problem is a system that locates a crash site on a digital map of the airport automatically and transmits this location to aircraft rescue and fire fighting services.

Navigation of aircraft rescue and fire fighting vehicles to crash sites is an issue that can be solved with today's technology. Sophisticated radio navigation systems such as the global positioning system (GPS) provide precise positioning capability. This position information, combined with digital maps of the airport area, can be displayed on a geographic map or heads-up display (HUD) to guide the crews.

Negotiating terrain and locating obstacles in low visibility conditions is an important capability that aircraft rescue and fire fighting services currently do not possess. The only aids that rescue services currently use for improving vision under poor visibility conditions are windshield wipers and headlights. These devices often do not improve visibility enough to allow rescue teams to drive safely at the high speeds necessary to reach a crash site within a reasonable time. One aid that would provide improvement is a forward looking infrared device (FLIR). FLIRs currently are used by the military to improve visibility at night and during severe weather conditions. The FLIR system needs to be fully functional as soon as the fire equipment departs the fire station facility. Exit time typically is under 30 seconds from the time of accident notification. On-line and operational equipment should in no way impede the ability of the aircraft rescue and fire fighting services to respond. Equipment is to be automated and is to necessitate little attention by the truck operator.

C-3 General Requirements. A driver's enhanced vision system (DEVS) is required in an aircraft rescue and fire fighting vehicle for airport emergency equipment. It facilitates faster and safer travel to emergency situations at night and in adverse weather conditions. It provides a substantial increase in the ability to locate people, other aircraft, vehicles, and debris at the emergency site. Its ability to allow the driver to see through flames, smoke, and fog during both the day and night provides ARFF vehicles with a significant increase in effectiveness in every phase of emergency operations.

The DEVS requires a transparent window display (TWD), which is often called a heads-up display (HUD), combined with a global positioning system (GPS) and geographic information system (GIS), on-board sensors, a central data and command RF link (radio communications), and a forward looking infrared (FLIR) sensor. These elements are to be integrated into a single functional system. A validation demonstration program is necessary to provide the quantitative information needed to justify the DEVS and refine it for the ARFF services application.

C-4 Operating Scenarios and Capabilities.

Mission Description

From the moment that an alert is received until the end of the emergency, the ARFF services mission is subject to stress and uncertainty. At any given moment, day or night, the equipment needs to be fully functional within a few seconds, regardless of adverse weather. Often vehicles and aircraft are positioned on the runways and taxiways in unusual or unexpected locations. In the event of an aircraft accident, victims and debris can be present anywhere on the airport. At the same time, the large size of modern airports, with multiple parallel runways and taxiways, places a priority on the ability to travel at high speed to the emergency site.

Once ARFF services have arrived at the location, the ability to assess the situation is crucial to carrying out the mission. The information available to the vehicle operator contributes directly to the level of performance of the ARFF mission. This information needs to be obtained without any increase in the workload. The DEVS reduces the impact of night conditions, adverse weather, fire, and smoke so that the operator's performance approaches that achieved during the optimum daylight scenario.

To achieve this goal, information is to be provided in an easily recognizable form, without the need for vehicle operator intervention. Rescue vehicle location, the location of the emergency, the location of other vehicles (ground and aircraft), the location of people, and the location of debris are the basic data needed (and normally available during the least difficult situations). The condition of the aircraft, location of victims, presence and location of spilled burning fuel, and location of other ARFF personnel also are crucial. In addition, the possible presence of toxic gases caused by spilled or burning cargo needs to be determined to provide for a safe response to the situation. Finally, since multiple vehicles and ARFF crews are always involved in most emergency situations, a centralized command and control system is needed to coordinate the activities of all elements of the emergency response team. The DEVS is one element of this command and control system.

C-5 Required Capabilities. The DEVS provides an increase in the knowledge available to the emergency crew. The crew are able to see through fog, rain, sleet, and snow. The crew are able to see through smoke and flames in and around the burning aircraft, to detect the position of evacuees and trapped passengers, and to distinguish among the debris to move into a position for fire fighting. They are able to apply extinguishing agents to the hottest areas of the burning fire more precisely. They also can track other fire fighters through the smoke and fire while rescue efforts are under way.

The FLIR device provides the ARFF operator with the ability to detect debris and other vehicles (stationary or moving) in the vicinity, as well as to detect passengers evacuating from the aircraft. The FLIR detector can electrocute humans in a smoke or fog environment where normal vision is inadequate. The FLIR stores information for normal driving conditions. The FLIR uses the brighter-than-background standard runway and taxiway lights, which are detected as it travels to the site.

C-6 System Elements. The elements of the DEVS for the ARFF vehicle demonstration include a forward looking infrared device (FLIR), a transparent window display (TWD) or heads-up display (HUD), and a global positioning system (GPS) with geographic information system

(GIS) or mapping.

C-7 Forward Looking Infrared Device. The FLIR is a high resolution infrared detector. It is enhanced with wide dynamic range processing for increased penetration of smoke and fog. The FLIR contains a two-dimensional focal plane array using platinum silicide as the detector material. It operates at wavelengths from 8 micrometers to 12 micrometers and has a sensitivity of 32.2°F (0.1°C). An alternate FLIR of 3 micrometers to 5 micrometers with similar sensitivity also is implemented to establish whether the shorter wavelength provides significant benefits in the smoke environment. A key element in the use of the FLIR device for this application includes a total hands-off automation philosophy. Rapid cool-down is another function dictated by the nature of FLIR detectors. To achieve the best performance, these detectors should be cooled to very low temperatures [in the range of –454°F (270.2°C)]. The cooling systems that have been developed have an operating life of about 2500 hours. Rapid cool-down or extended standby life cycle is considered essential to an ARFF application. Zero (0) or near-zero time start-up is an operational requirement for effectiveness.

C-8 Dynamic Range Issues. To detect people and debris, the FLIR has a sensitivity of approximately 32.2°F (0.1°C). At the same time, the FLIR can be expected to deliver this sensitivity in the presence of flames that couldreach temperatures of 1832°F (1000°C). In order to accomplish this, the FLIR operates over an instantaneous dynamic range of about 10,000: 1.

C-9 Transparent Window Display. The transparent window display system hardware consists of a projector, an optical element, and a symbol generator to provide information to an operational position. The symbol generator provides data to the projector by means of dedicated signal cables. The symbol generator has the capability to receive and to process data links from up to six video inputs and two serial inputs while formatting messages based on a control program. The control program uses the data's priority, refresh rate, and other site-specific criteria to implement the sequence and content of the information presentation.

C-10 Projector. The DEVS projector is a high-brightness CRT, monochrome emitter that creates and projects a focused image onto the window of the ARFF vehicle. The projector is designed to be placed 60 in. to 72 in. (152.4 cm to 182.9 cm) from the window. There are optional mounting schemes that allow the projector to be mounted off-axis from the window to accommodate existing mechanical obstructions. The projector is to be equipped to accept standard signal inputs that include RS-170 to utilize the TWDs as a simple replacement of an existing heads-down display (HDD).

C-11 Optical Element. The optical element is mounted to the window of the ARFF vehicle to act as a dynamic display surface within the truck cab. The optical element should be 6 in.^{2} to 12 in.^{2} (38.7 cm^2 to 77.4 cm^2) and affixed to a selected location on the window with room temperature vulcanizing material. The location should be predefined to reflect data in a uniform manner that is specified by both lateral and vertical angles perpendicular to the plane of the window. The viewing zone should offer a lateral reflection angle of 30 degrees and a vertical reflection angle of 15 degrees. The information is to be presented in a bright green color and is to be focused at the plane of the window. The DEVS is not to obstruct the view to the outside of the vehicle.

C-12 Symbol Generator. The symbol generator is to be a microcomputer-based system designed for rack mounting in an equipment bay. This remote computer offers the capability to interface directly with a selected set of on-board data channels or discrete indicator inputs and is linked with a GPS tracker and a FLIR. The symbol generator is programmed with the mission-specific control scheme and operates in an automatic mode. There is a keyboard and monitor option that supports on-site changes of the data communications and control routines. The symbol generator formats data “pages” and routes this information to the appropriate projector based on priority or currency or on demand. The symbol generator is capable of being configured to accept a variety of standard signal inputs including RS-232, RS-422, and RS-170.

C-13 Global Positioning System. A global positioning system (GPS) receiver is to be mounted on the ARFF vehicle and interfaced with the transparent window display system for display of position information. The GPS is to be a six-channel receiver capable of tracking up to eight satellites. The GPS receiver calculates new position data once every second. Position accuracy is specified at a maximum of 82 ft (25 m), with a typical accuracy of about 32.8 ft to 49.2 ft (10 m to 15 m). An additional ground-based differential transmitter on the airfield provides accuracy from 3.3 ft to 9.8 ft (1 m to 3 m).

C-14 Geographic Information System. The airport mapping system by which the ARFF vehicle is navigated can be developed by several methods. One method being considered is the digital reconstructive method. This is accomplished by taking an aerial photograph of the airport and digitizing it so it then can be displayed on the computer screen for mapping. This method, as it is developed, could provide the increased local terrain and hazards definition needed by the ARFF vehicle to travel on and around the airfield. Additional mapping capability with definitions of 1 mi, 3 mi, and 10 mi (1.6 m, 4.8 m, and 16.1 m) provide for call-up mapping in the event of an accident off the airport operational areas. Digital aerial mapping is an emerging technology that provides three-dimensional hazard definition of streams, swales, and drainage culverts, as well as other hazards that could impede the progress of the rescue.

C-15 Computer Information Enhancements. Once an operational computer is placed in the ARFF vehicle, it provides a host of other fire fighting capabilities. Fire fighters are able to have the complete airport's emergency plan available in the computer with menu-driven software. Toxic and hazardous material indexes can be provided. Complete instructions on emergency door and entryway door operations for every type of commercial aircraft can be provided.

C-16 Vehicle Electrical Upgrade. Because of the need for better power sources, vehicles with new technology equipment need to undergo some modifications to the existing electrical systems. Computers and electronically-controlled devices need smooth-filtered and stable voltage sources. The equipment targeted for installation is modified to operate in the voltage ranges used on the existing vehicles. This usually is 12 v or 24 v dc. Special power converters and voltage stabilizers are to be considered. There also are requirements for the addition of 115 v ac in some cases. Operating off portable generator power sources that might already exist on some of these vehicles does not, in most cases, provide, the smooth, stabilized power sources of these requirements. Transformer rectifiers and power converters do not provide a major challenge for the technological requirements of this program. Low-cost portable battery back-up systems also should be considered to provide power for start-up of the vehicle as well as accidental shutoff of the vehicle system supply. The cost for these required voltage sources is minimal when compared to the trouble-free environment that they provide for the electronic boards and computer systems.

C-17 Final Assessment. The object of this assessment program is to provide information about the new computer-based equipment and vision enhancement devices that help the airport rescue services perform their assigned mission under suboptimal visibility conditions. The cost of installing this equipment can be justified by the need to operate aircraft under these poor visibility conditions. If operations are conducted that allow the aircraft to take off and land under poor visibility conditions, it is reasonable to expect that additional requirements for fire fighting response under low visibility conditions will be established.

The technology needed to perform the driver's enhanced vision system (DEVS) is available now. Although the equipment can be bought off the shelf, installation necessitates some additional research effort because aircraft rescue and fire fighting mission requirements were not considered in the research efforts that produced this technology. In each case, the individual elements of the DEVS considered the fact that the proposed system should require low operational workload by the operator. Each piece of the system endeavors to use current technological equipment with some hardware and software modifications. Finally, the DEVS should be designed for easy installation and a maintenance-free duty life cycle or at the least a modular rack installation design allowing the removal and replacement of components by current maintenance personnel without adding to the personnel burden of a rescue and fire fighting service.

Finally, the most important issue is cost. Historically, this technology is expensive. Some of the reasons for these high costs were dictated by low production runs and the survivability conditions for which the equipment originally was designed. Equipment meeting the rigorous requirements necessary for military applications can add many thousands of dollars to the final purchase price. It is hoped that, with the careful redesign and unique adaptation of existing equipment designs and unit cost price decreases, the cost of using this technology in an aircraft rescue fire fighting vehicle can be reduced substantially in the near future.

C-18 Driver's Enhanced Vision System Guidelines.

C-18.1 DEVS Performance Characteristics. The driver's enhanced vision system (DEVS) is an integrated system of sensors, computers, and navigational equipment designed to improve the response and operation of ARFF crews in low visibility conditions. The DEVS consists of three components: a night or low visibility capability, a vehicle navigation capability, and a vehicle tracking capability, which are integrated using a digital radio data link.

To meet the DEVS requirements, systems need to integrate all three components cohesively. Each component should be integrated into the vehicle's normal operations through a systematic approach of understanding and adapting the technology to the needs of the fire fighting population.

In the sections that follow, the base performance characteristics are detailed. It is important to note that technology development in the enhanced vision area is progressing rapidly; therefore, the criteria that follows should be considered minimal. Questions regarding specific production systems, new performance capabilities, or recommended systems should be directed to the FAA's airports office.

C-18.2 Low Visibility Capability. The intent of the low visibility capability is to provide an enhanced picture of the environmental scene through the use of a chamber or other sensor system displayed inside of the cab. For the immediate future, it appears that forward looking infrared (FLIR) technology holds the most promise for aiding visibility in smoke, fog, and haze and at night. The minimum recommended performance characteristics of the low visibility system are provided below:

(a) **General.**

Expected worst case visibility	0 ft range/0 ft ceiling
Time to operational	≤30 sec
Detection of humans	500 ft (152.4 m), temp: –20°F to 115°F (28.9°C to 46.1°C), moving 55 mph (88.5 km/h), clear conditions
	500 ft (152.4 m), temp: –20°F to 115°F (28.9°C to 46.1°C), moving 50 mph (80.5 km/h), light fog conditions
	400 ft (121.9 m), temp: –20°F to 115°F (28.9°C to 46.1°C), moving 40 mph (64.4 km/h), heavy fog conditions
	400 ft (121.9 m), temp: –20°F to 115°F (28.9°C to 46.1°C), moving 40 mph (64.4 km/h), smoke conditions
	300 ft (91.4 m), temp: –20°F to 115°F (28.9°C to 46.1°C), moving 35 mph (56.3 km/h), rain/snow conditions
Detection of GA aircraft	2500 ft (762.0 m), temp: –20°F to 115°F (28.9°C to 46.1°C), moving 55 mph (88.5 km/h), clear conditions
	1000 ft (304.8 m), temp: –20°F to 115°F (28.9°C to 46.1°C), moving 50 mph (80.5 km/h), light fog conditions
	500 ft (152.4 m), temp: –20°F to 115°F (28.9°C to 46.1°C), moving 40 mph (64.4 km/h), heavy fog conditions
	500 ft (152.4 m), temp: –20°F to 115°F (28.9°C to 46.1°C), moving 40 mph (64.4 km/h), smoke conditions
	500 ft (152.4 m), temp: –20°F to 115°F (28.9°C to 46.1°C), moving 35 mph (56.3 km/h), rain/snow conditions

Detection of objects near fires	People, debris, wreckage, and equipment within 20 ft (6.1 m) of a 6 ft (1.8 m) diameter Jet A fuel fire from a range of 1000 ft (304.8 m)

(b) **FLIR Specific.**

IR waveband	Long wave IR energy (8µm to 12 µm)
Video output	RS-170 or industry standard video
Gain and level controls	Automatic
Horizontal field of view	≥28 degrees (40 degrees preferred)
Vertical field of view	>20 degrees, aspect ratio to match vertical
Lens clearing capability	Windshield wiper, high pressure air, or equivalent
Temperature and humidity changes	Changes in ambient temperature and humidity should not result in condensation inside the FLIR housing or optics assembly
Mounting	On top of vehicle with pan and tilt capability, remote-control equipped, line of sight aligned with driver's line of sight
Video monitor	8 in. to 10 in. (6.2 cm to 25.4 cm) diagonal display mounted near driver's line of sight *Alternative*: Heads-up display with field-of-view to match FLIR

C-18.3 Navigation Capability. The intent of the navigation capability is to allow for accurate positioning of the vehicle on or around the airport surface. The navigation capability should provide a depiction of the vehicle, notable landmarks, roadways, and other guidance aids. Information should be provided to the driver in a meaningful form appropriate to the needs of the fire response.

The navigation capability consists of three main components: a global positioning system (GPS) receiver, a computer system containing supporting maps and navigation information, and a display/control system for driver information.

For full capability on the airport, the DEVS should incorporate both capabilities into the design. The performance characteristics of the components in the above list are as follows:

Position availability	Computed position within 30 sec/hr/day, 7 days/week
Accuracy	Two-dimensional position within 15 ft (4.6 m)

Dead reckoning	Coasting capability when satellite track is lost due to shadowing
Position update rate	< 1/sec
Initialization and operation	Fully automatic
Map — levels of detail	Level 1 — Airport operations area
	Level 2 — Airport property boundary
	Level 3 — 5 mi (8 km) radius of the airport center; either variable or fixed zooms within each level should be provided
Map — orientation	North-up or heading-up, selectable (Note: Heading-up orientation is required for situational awareness in low visibility conditions and unfamiliar areas)
Map — visual orientation cues	Vehicle orientation, vehicle heading, direction of low visibility coverage
Driving cues	Range/bearing indicator in line-of-sight (on FLIR display or separate)
Data link — error checking	Standard error checking
Data link — frequency selection	Selectable to airport location
Display — color	≥ 256 colors

C-18.4 Tracking Capability. The tracking capability components include: Differential GPS (DGPS) correction software, data link hardware/software, and an integrated display/control system for command center operations. The command center can be either fixed or mobile, depending on individual airport ARFF operations. This capability is intrinsically tied to the tracking capability, which allows for the monitoring of the positions of other vehicles, the crash site, identified victims, and other factors, as well as linkage to a centralized display for emergency coordination.

Map — orientation	North-up with dynamic zoom and pan
Data link — error checking	Standard error checking
Data link — frequency selection	Selectable to airport location
Display — color	Large high-resolution monitor [>19 in. (>48.3 cm) diagonal color monitor, 1280 × 1024 resolution]

C-19 Glossary of Technical Terms

Aircraft Rescue and Fire Fighting (ARFF). Formerly known in the fire fighting industry as crash, fire, and rescue.

Cool-Down in the Operational Environment of an Infrared Detector. Term used to describe the period of time needed for the refrigeration unit of the optical sensor to cool the unit to approximately −454°F (−270.2°C) below zero (0). This cool-down mode provides the necessary sensitivity of 10,000: 1 for infrared thermal detection.

Driver's Enhanced Vision System (DEVS). A vision enhancement system utilizing several electronic and computer-based components that aids in improving sight as well as movement or navigation around the airport during reduced visibility operational conditions.

Forward Looking Infrared (FLIR). A heat detector device that allows the viewer to see radiant heat projected from objects. These devices work in the micron band of the infrared spectrum (e.g., 8 µm to 12 µm).

Geographic Information System (GIS). A device that allows an aerial map of the airport to be displayed with markers that move along the image as the vehicle changes position.

Global Positioning System (GPS). A device that picks up signals from orbiting satellites and determines positions of location on earth by reference to longitude and latitude.

Heads-Up Display (HUD). The military name for a device that allows a person to look and operate a device while viewing through the cockpit window of an aircraft. This device displays information on the cockpit window.

Transparent Window Display (TWD). An electronic device that projects an image on a special coated glass or plastic that also allows the viewer to see through the clearplate with a slight reduction in visibility.

Appendix D Civil Aircraft Accident Investigation

This Appendix is not a part of the recommendations of this NFPA document but is included for informational purposes only.

D-1 In the United States of America, major aircraft accidents are investigated by the National Transportation Safety Board (NTSB), 800 Independence Avenue SW, Washington, DC 20591. In some instances responsibility for investigation is delegated by the Board to the Federal Aviation Administration (FAA).

RESCUE: The occupants.

GUARD: The wreckage — Allow no one inside the wreckage area other than those necessary for occupant removal, fire fighting, and the possible removal of mail and cargo where necessary to protect it from further damage. Items removed for protection must be retained locally for examination by a Federal Air Safety Investigator.

ADVISE: The county coroner/medical examiners — Fatally injured occupants of the aircraft should be held for possible pathological or toxicological examination or both prior to embalment.

IDENTIFY: The position of fatalities — Prior to removing the remains of fatally injured occupants, tag or otherwise identify each body, and mark its location in the wreckage or on the ground (photograph in position, if possible).

PERMIT: News media coverage — Accredited news media may be permitted to enter and photograph the area as long as the wreckage is not disturbed.

NOTIFY: The local authorities, the Safety Board, FAA.

D-2 National Transportation Safety Board Rules.

Title 49 Transportation

Chapter VIII — National Transportation Safety Board

Revised: March 20, 1985

Part 830 Notification and Reporting of Aircraft Accidents or Incidents and Overdue Aircraft, and Preservation of Aircraft Wreckage, Mail, Cargo, and Records.

Authority: Title VII, Federal Aviation Act of 1958, as amended, 72 Stat. 781, as amended by 76 Stat. 921 (49 U.S.C. 1441 et seq.), and the Independent Safety Board Act of 1974, Pub. L. 93-633,88 Stat. 2166 (49 U.S.C. 1901 et seq.).

Subpart A — General.

830.1 Applicability.

This part contains rules pertaining to:

(a) Notification and reporting aircraft accidents and incidents and certain other occurrences in the operation of aircraft when they involve civil aircraft of the United States wherever they occur, or foreign civil aircraft when such events occur in the United States, its territories or possessions.

(b) Preservation of aircraft wreckage, mail, cargo, and records involving all civil aircraft in the United States, its territories or possessions.

830.2 Definitions.

As used in this part the following words or phrases are defined as follows:

“Aircraft accident” means an occurrence associated with the operation of an aircraft which takes place between the time any person boards the aircraft with the intention of flight and all such persons have disembarked, and in which any person suffers death or serious injury, or in which the aircraft receives substantial damage.

"Fatal injury" means any injury which results in death within 30 days of the accident.

"Incident" means an occurrence other than an accident, associated with the operation of an aircraft, which affects or could affect the safety of operations.

"Operator" means any person who causes or authorizes the operation of an aircraft, such as the owner, lessee, or bailee of an aircraft.

"Serious injury" means any injury which (1) requires hospitalization for more than 48 hours, commencing within 7 days from the date the injury was received; (2) results in a fracture of any bone (except simple fractures of fingers, toes, or nose); (3) causes severe hemorrhages, nerve, muscle, or tendon damage; (4) involves any internal organ; or (5) involves second or third degree burns, or any burns affecting more than 5 percent of the body surface.

"Substantial damage" means damage or failure which adversely affects the structural strength, performance, or flight characteristics of the aircraft, and which would normally require major repair or replacement of the affected component. Engine failure or damage limited to an engine if only one engine fails or is damaged, bent fairings or cowling, dented skin, small punctured holes in the skin or fabric, ground damage to rotor or propeller blades and damage to landing gear, wheels, tires, flaps, engine accessories, brakes, or wingtips, are not considered "substantial damage" for the purpose of this part.

Subpart B — Initial Notification of Aircraft Accidents, Incidents, and Overdue Aircraft.

830.5 Immediate notification.

The operator of an aircraft shall immediately, and by the most expeditious means available, notify the nearest National Transportation Safety Board, field office[1] when:

(a) An aircraft accident or any of the following listed incidents occur:

1. Flight control system malfunction or failure;

2. Inability of any required flight crewmember to perform normal flight duties as a result of injury or illness;

3. Failure of structural components of a turbine engine excluding compressor and turbine blades and vanes;

4. In-flight fire; or

5. Aircraft collide in flight.

(b) An aircraft is overdue and is believed to have been involved in an accident.

830.6 Information to be given in notification.

The notification required in section 830.5 shall contain the following information, if available:

(a) Type, nationality, and registration marks of the aircraft;

(b) Name of owner, and operator of the aircraft;

(c) Name of the pilot-in-command;

(d) Date and time of the accident;

(e) Last point of departure and point of intended landing of the aircraft;

(f) Position of the aircraft with reference to some easily defined geographical point;

(g) Number of persons aboard, number killed, and number seriously injured;

(h) Nature of the accident, the weather, and the extent of damage to the aircraft, so far as is known; and

(i) A description of any explosives, radioactive materials, or other dangerous articles carried.

Subpart C — Preservation of Aircraft Wreckage, Mail, Cargo, and Records.

830.10 Preservation of aircraft wreckage, mail, cargo, and records.

(a) The operator of an aircraft involved in an accident or incident for which notification must be given is responsible for preserving to the extent possible any aircraft wreckage, cargo, and mail aboard the aircraft, and all records, including all recording mediums of flight, maintenance, and voice recorders, pertaining to the operation and maintenance of the aircraft and to the airmen until the Board takes custody thereof or a release is granted pursuant to section 831.10(b).

(b) Prior to the time the Board or its authorized representative takes custody of aircraft wreckage, mail, or cargo, such wreckage, mail, or cargo may not be disturbed or moved except to the extent necessary:

1. To remove persons injured or trapped;

2. To protect the wreckage from further damage; or

3. Where it is necessary to move aircraft wreckage, mail, or cargo, sketches, descriptive notes, and photographs shall be made, if possible, of the original position and condition of the wreckage and any significant impact marks.

(c) The operator of an aircraft involved in an accident or incident shall retain all records, reports, internal documents, and memoranda dealing with the accident or incident, until authorized by the Board to the contrary.

Subpart D — Reporting of Aircraft Accidents, Incidents, and Overdue Aircraft.

830-15 Reports and statements to be filed.

(a) *Reports.* The operator of an aircraft shall file a report on Board Form 6120.1 or Board Form 6120.2[2] within 10 days after an accident, or after 7 days if an overdue aircraft is still missing. A report on an incident for which notification is required by section 830.5(a) shall be filed only as requested by an authorized representative of the Board.

(b) *Crewmember Statement.* Each crewmember, if physically able at the time the report is submitted, shall attach a statement setting forth the facts, conditions and circumstances relating to the accident or incident as they appear to him. If the crewmember is incapacitated, he shall submit the statement as soon as he is physically able.

(c) *Where to File the Reports.* The operator of an aircraft shall file any report with the field office of the Board nearest the accident or incident.

NOTE: The reporting and recordkeeping requirements contained herein have been approved by the Office of Management and Budget in accordance with the Federal Report Act of 1942.

Signed at Washington, DC, on September 4, 1980.

James B. King

Chairman

[1]The National Transporation Safety Board field offices are listed under U. S. Government in the telephone directories in the following cities: Anchorage, AK; Atlanta, GA; Chicago, IL; Denver, CO; Fort Worth, TX; Kansas City, MO; Los Angeles, CA; Miami, FL; New York, NY; Seattle, WA.

[2]Forms are obtainable from the Board field offices (see footnote 1), the National Transportation Safety Board, Washington, DC 20594, and the Federal Aviation Administration, Flight Standards District Office.

Appendix E Sample Mutual Aid Agreements

This Appendix is not a part of the recommendations of this NFPA document but is included for informational purposes only.

E-1 USAF Mutual Aid Agreement (AFR 92-1).

This agreement, entered into this ________ day of______________, 19___, between the Secretary of the Air Force, acting pursuant to the authority of the Act of May 27, 1955 (69 stat, 66), and (fire organization) is for the purpose of securing to each the benefits of mutual aid in fire prevention, in the protection of life and property from fire, and in fire fighting.

It is agreed that:

(a) Upon request to a representative of the ________ Air Force Base Fire Department by a representative of the (fire organization), fire fighting equipment and personnel of the _____________________ Air Force Base Fire Department will be dispatched to any point within the area for which the (fire organization) normally provides fire protection as designated by the representative of the (fire organization).

(b) Upon request to the representative of the (fire organization) by a representative of _________ Air Force Base Fire Department, fire fighting equipment and personnel of the (fire organization) will be dispatched to any point within the fire fighting jurisdiction of the __________ Air Force Base Fire Department as designated by the representative of the __________ Air Force Base Fire Department.

(c) Any dispatch of equipment and personnel pursuant to this agreement is subject to the following conditions:

1. Any request for aid hereunder shall include a statement of the amount and type of equipment and number of personnel requested, and shall specify the location to which the equipment and personnel are to be dispatched, but the amount and type of equipment and number of personnel to be furnished shall be determined by a representative of the responding

organization.

2. The responding organization shall report to the officer in charge of the requesting organization at the location to which the equipment is dispatched and shall be subject to the orders of that official.

3. A responding organization shall be released by the requesting organization when the services of the responding organization are no longer required or when the responding organization is needed within the area for which it normally provides fire protection.

4. In the event of a crash of aircraft owned or operated by the United States or military aircraft of any foreign nation within the area for which the (fire organization) normally provides fire protection, the Chief of the ___________________ Air Force Base Fire Department or his representative may assume full command upon his arrival at the scene of the crash.

(d) Each party waives all claims against every other party for compensation for any loss, damage, personal injury, or death occurring as a consequence of the performance of this agreement.

(e) No party shall be reimbursed by any other party for any costs incurred pursuant to this agreement.

(f) All equipment used by (fire organization) in carrying out this agreement will, at the time of action hereunder, be owned by it; and all personnel acting for (fire organization) under this agreement will, at the time of such action, be an employee or volunteer member of (fire organization).

E-2 Typical Civil Airport Department Mutual Aid Agreement.

The following mutual aid agreement example is based on procedures used by the Seattle-Tacoma International Airport supplied through the courtesy of R. E. Smith, Fire Chief.

This agreement, made and entered into this __________ by and between the___________________________________ and the____

WITNESSETH:

WHEREAS, each of the parties hereto maintains equipment and personnel for the suppression of fires within its own jurisdiction and areas, and

WHEREAS, the parties hereto desire to augment the fire protection available in their establishments, district agencies and municipalities in the event of large fires, conflagrations, and natural or technological disasters, and

WHEREAS, the agencies entering into this Agreement have an interest in providing mutual assistance in emergencies for which each respective fire department has the capabilities to respond, and

THEREFORE BE IT AGREED THAT:

(a) Whenever it is deemed advisable by the commanding officer of a fire department belonging to a party to this Agreement, or whenever the commanding officer of any such fire department is actually present at an emergency incident, such commanding officer may request assistance for the purpose of extinguishing, controlling, or aiding in the extinguishing or controlling of fires, or in the mitigation of emergency medical service incidents from the fire departments which are signatory to this Agreement. Under the terms of this Agreement, such commanding officer is authorized to make such a request and the commanding officer of the department receiving the request or authorized subordinates, shall forthwith take the following action:

1. Immediately determine if apparatus and personnel can be spared in response to the call;

2. What apparatus and personnel might most effectively be dispatched;

3. The exact mission to be assigned in accordance with the detailed plans and procedures of operation drawn in accordance with this Agreement by the managing representatives of the fire department concerned;

4. Dispatch such apparatus and personnel as the responsible officer receiving the call reasonably believes should be sent, with complete instructions as to the mission, in accordance with the terms of this Agreement and pursuant to the instructions received in the request for assistance.

(b) The tendering of assistance under the terms of this Agreement shall not be mandatory, but the party receiving the request of assistance should immediately inform the requesting agency if, for any reason, assistance cannot be rendered.

(c) Each party to this Agreement waives all claims against the other party or parties for compensation for any loss, damage, personal injury, or death occurring in consequence of the performance of this Agreement.

(d) Each party to this Agreement shall maintain its own insurance coverage for equipment and personnel.

(e) All services performed under this Agreement shall be rendered without reimbursement of either party or parties.

(f) The commanding officer of the fire department requesting assistance shall not relinquish responsibility for mitigating the emergency incident to those officers responding pursuant to the terms of this Agreement. A senior officer of a responding mutual aid department will make him/herself available to the commanding officer for consultation as a resource person, to assist in tactical or strategical decisions during the emergency. As often as is practically possible, the mutual aid departments will remain intact under the direct supervision of the highest ranking officer from their own department. Direction for the responding department’s fire fighters’ and subordinate officers’ activities will, however, come from the commanding officer of the fire department initiating the request for assistance.

(g) The chief fire officers and personnel of the fire departments of both parties to this Agreement are invited and encouraged, on a reciprocal basis, to frequently visit each other’s activities for guided familiarization tours consistent with local security requirements and, as feasible, to jointly conduct pre-fire planning inspections and drills.

(h) The commanding officers of the fire departments of the parties of this Agreement are authorized to meet and draft any detailed plans and procedures of operation necessary to effectively implement this Agreement. Such plans and procedures of operations shall become effective upon ratification by the signatory parties.

(i) This Agreement shall become effective upon the date hereof and shall remain in full force and effect until cancelled by mutual agreement of the parties hereto or by written notice by one party to the other party, giving ten (10) days notice of said cancellation.

IN WITNESS THEREOF, the parties hereto have executed this Agreement at ________________________, Washington, on the day and year first above written.

PORT OF SEATTLE FIRE DEPARTMENT

Appendix F Referenced Publications

This Appendix is not a part of the recommendations of this NFPA document but is included for informational purposes only.

F-1 The following documents or portions thereof are referenced within this guide for informational purposes only and thus should not be considered part of the recommendations of this document. The edition indicated for each reference is the current edition as of the date of the NFPA issuance of this document.

F-1.1 NFPA Publication. National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.

NFPA 422, *Guide for Aircraft Accident Response*, 1994 edition.

Fire Protection Guide on Hazardous Materials.

F-1.2 IATA Publication. International Air Transport Association Headquarters, IATA Building, 2000 Peel Street, Montreal, Canada H3A 2R4.

Restricted Articles Regulations.

F-1.3 U.S. Government Publication. Office of the Federal Register, National Archives and Records Service, General Services Administration, Washington, DC 20408.

Title 49, *Code of Federal Regulations*, Part 175, “Transportation.”

F-2 Bibliographical References. *The following publications are included in the Appendix for informational purposes only*.

F-2.1 ICAO Publications. International standards and recommended practices are promulgated by the International Civil Aviation Organization, 1000 Sherbrooke Street West, Montreal, Quebec, Canada H3A 2R2.

Aerodromes (Annes 14), 8th edition, March 1983.

Airport Services Manual, Part 1: "Rescue and Fire Fighting," second edition, 1984.

Emergency Response Guidance for Aircraft Incidents Involving Dangerous Goods, first edition, March 1987.

F-2.2 U.S. Government Publications. Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402.

F-2.2.1 FAR Part 139. Part 139 is sold on a subscription basis by the Superintendent of Documents. Subscribers will receive changes to this part automatically.

F-2.2.2 Federal Aviation Administration Publications. Available from Department of Transportation, Distribution Unit, M-494.3, Washington, DC 20590.

Advisory Circulars. This listing is limited to those free advisory circulars relating to aircraft rescue and fire fighting services. For a complete listing of FAA advisory circulars, write to the address above and request a copy of the latest "Advisory Circular Checklist and Status of Other FAA Publications." This checklist is also published periodically in the Federal Register.

150/5200-12A, *Fire Department Responsibility in Protecting Evidence at the Scene of an Aircraft Accident* (4-8-85) (AAS-100). Furnishes general guidance for airport employees, airport management, and other personnel responsible for fire fighting and rescue operations, at the scene of an aircraft accident, on the proper presentation of evidence.

150/5200-15C, Announcement of Availability — International Fire Service Training Association's Manual 206, *Aircraft Fire Protection and Rescue Procedures* (second edition, 1978) (8-26-82) (AAS-100). Explains the nature of the manual and tells how it can be obtained.

150/5200-18A, *Airport Safety Self-Inspection* (12-18-85) (AAS-310). Suggests functional responsibility, procedures, a checklist, and schedule for an airport safety self-inspection.

150/5200-21A, Announcing the Availability of U.S. Air Force Technical Order (T.O. 00-105E-9) *Aircraft Emergency Rescue Information* (2-24-81) (AAS-100). Explains the nature of the Technical Order and tells how it can be obtained.

150/5210-2A, *Airport Emergency Medical Facilities and Services* (11-27-84) (AAS-300). Provides information and advice so that airports can take specific voluntary pre-incident planning actions to ensure at least minimum first aid and medical readiness appropriate to the size of the airport in terms of permanent and transient personnel.

150/5210-6C, *Aircraft Fire and Rescue Facilities and Extinguishing Agents* (1-28-85) (AAS-100). Outlines scales of protection considered as the recommended level compared with the minimum level in Federal Aviation Regulation Part 139.49 and tells how these levels were established from test and experience data.

150/5210-13, *Water Rescue Plans, Facilities, and Equipment* (5-4-72) (AAS-300). Suggests planning procedures, facilities, and equipment to effectively perform rescue operations when an aircraft lands in a body of water, swamp, or tidal area where normal aircraft fire fighting and rescue service vehicles are unable to reach the accident scene.

150/5210-14, *Airport Fire and Rescue Personnel Protective Clothing* (3-12-86) (AAS-100). Developed to assist airport management in the development of local procurement specifications for an acceptable, cost-effective proximity suit for use in aircraft rescue and fire fighting operations.

150/5210-15, *Airport Rescue and Fire Fighting Station Building Design* (7-30-87) (AAS-100). Provides standards and guidance for planning, designing, and constructing and airport rescue and fire fighting station.

150/5210-58, *Painting, Marking, and Lighting of Vehicles Used on an Airport* (7-11-86) (AAA-120). Provides guidance, specifications, and standards, in the interest of airport personnel safety and operational efficiency, for painting, marking, and lighting of vehicles operating in the airport air operations areas.

150/5210-78, *Aircraft Fire and Rescue Communications* (4-30-84) (AAS-120). Provides guidance and information for planning and implementing an airport communications system for airport fire and rescue service.

150/5220-4A, *Water Supply Systems for Aircraft Fire and Rescue Protection* (12-11-85) (AAS-120). Provides guidance for the water source selection and standards for a water distribution system designed to support aircraft rescue and fire fighting (ARFF) service operations on airports.

150/5220-9, *Aircraft Arresting Systems for Joint Civil/Military Airports* (4-6-70) (AAS-300). Updates existing policy and describes and illustrates the various types of military aircraft emergency arresting systems that are now installed at various joint civil/military airports. It also informs users of criteria concerning installations of such systems at joint civil/military airports.

150/5220-10, *Guide Specification for Water/Foam Type Aircraft Fire and Rescue Trucks* (5-26-72) (Consolidated reprint incorporates changes 1 and 2) (AAS-100). Assists airport management in the development of local procurement specifications.

150/5220-14A, *Airport Fire and Rescue Vehicle Specification Guide* (2-25-85) (AAS-100). Assists airport management in the development of local procurement specifications.

150/5230-4, *Aircraft Fuel Storage, Handling, and Dispensing on Airports* (8-27-82) (AAS-300). Provides information on aviation fuel deliveries to airport storage and the handling, cleaning, and dispensing of fuel into aircraft.

150/5230-4, Chg. 1 (2-20-86).

150/5230-4, Chg. 2 (7-1-87).

150/5280-1, *Airport Operations Manual* (6-16-72) (AAS-310). Sets forth guidelines to assist airport operators in developing an Airport Operations Manual in compliance with the requirements of FAR Part 139.

150/5280-1, Chg. 1 (3-24-81).

150/5280-3, *Fire Fighting Exemptions Under the 1976 Amendment to the Federal Aviation Act* (2-4-77) (AAS-100). Outlines the type of information that can be used as justification in supporting petitions for exemption from a portion or all of the fire fighting and rescue requirements of Part 139.

150/5325-5C, *Aircraft Data* (6-29-87) (AAS-100). Presents a listing of principal aircraft weights and dimensions which affect airport facility design. It is to be used for guidance in airport development. Data presented are for common civil aircraft and those military aircraft which frequently utilize civil facilities.

150/5340-1E, *Marking of Paved Areas on Airports* (11-4-80) (AAS-200). Describes standards for marking paved runways, taxiways, closed and/or hazardous areas on airports.

150/5340-18B, *Standards for Airport Sign Systems* (8-21-84) (AAS-200). Contains the Federal Aviation Administration standards for use on airports.

150/5355-1A, *International Signs to Facilitate Passengers Using Airports* (11-3-71) (AAS-100). Informs airport authorities of the desirability to provide international signs and diagrammatic maps within terminal buildings and of the need of clearly marked road signs for airports.

150/5355-2, *Fallout Shelters in Terminal Buildings* (4-1-69) (AAS-100). Furnishes guidance for the planning and design of fallout shelters in airport terminal buildings.

150/5360-12, *Airport Signing and Graphics* (12-23-85) (AAS-110). Provides guidance on airport related signs and graphics.

150/5370-2C, *Operational Safety on Airports During Construction* (5-31-84) (AAS-300). Concerning operational safety on airports with special emphasis on safety during periods of construction activity, to assist airport operators in complying with Part 139.

150/5380-5A, *Debris Hazards at Civil Airports* (2-25-81) (AAS-100). Discusses problems of debris at airports, gives information on foreign objects, and tells how to eliminate such objects from operational areas.

F-2.2.3 United States Military Publications.

Air Force: Technical Manual 00-105E-9, *Aircraft Emergency (Fire Protection Information)*, available from HQ WR-ALC (MMEOTD), Robbins AFB, GA 31093.

Navy and Marine: NAVAIR 00-80R-14, *Aircraft Fire Fighting and Rescue Manual for US Naval and Marine Air Stations and Facilities*, available from Naval Air Technical Services Facility, 700 Robins Avenue, Philadelphia, PA 19111.

Army: *Technical Manual 5-315,* available from Superintendent of Public Documents, Public Documents Department, U.S. Government Printing Office, Washington, DC 20402.

F-2.3 Miscellaneous.

ASTM E 380, *Standard for Metric Practice*, 1993, American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103.

Advanced Techniques in Impact Protection and Emergency Egress from Air Transport Aircraft, R.G. Snyder Report, HEARD-AG 221, National Transportation Safety Board Accident Reports.

NFPA 403

1993 Edition

Standard for Aircraft Rescue and Fire Fighting Services at Airports

1993 Edition

This edition of NFPA 403, *Standard for Aircraft Rescue and Fire Fighting Services at*

Airports, was prepared by the Technical Committee on Aircraft Rescue and Fire Fighting and acted on by the National Fire Protection Association, Inc. at its Annual Meeting held May 24-27, 1993, in Orlando, FL. It was issued by the Standards Council on July 23, 1993, with an effective date of August 20, 1993, and supersedes all previous editions.

The 1993 edition of this document has been approved by the American National Standards Institute.

Changes other than editorial are indicated by a vertical rule in the margin of the pages on which they appear. These lines are included as an aid to the user in identifying changes from the previous edition.

Origin and Development of NFPA 403

Committee work leading to the development of a recommended practice by the Association commenced in 1947 following a request from the Civil Aeronautics Board (U.S.A.) for information on what constituted "adequate" ground fire fighting equipment and personnel for airports served by air carrier aircraft.

NFPA Committee work continued during 1948, and in 1949 the Association adopted a tentative text at its Annual Meeting held in San Francisco, CA. In 1952 a revised text was submitted for adoption by the Association, and unanimously accepted. Since its original adoption, this text has been revised periodically with editions issued in 1954, 1955, 1956, 1957, 1958, 1959, 1960, 1961, 1962, 1965, 1966, 1967, 1970, 1971, 1972, 1973, 1974, 1975, and 1978.

The 1988 edition comprised a complete revision to the text of the document to make it a standard and to segregate mandatory requirements from advisory material. Prior to the 1988 edition, all editions were recommended practices.

A Standing Subcommittee responsible for revising this standard was appointed by the Standards Council. This Standing Subcommittee was dissolved in 1992 with a change to the *Regulations Governing Committee Projects*. The work of revising this standard was continued by a Task Group appointed by the chairman. The following is a list of the members of the Task Group:

Task Group on Aircraft Rescue and Fire Fighting Services at Airports

Paul R. Robinson, Kennesaw, GA, Rep. Air Line Pilots Assn., Chair; Brian Boucher, Canadian Air Line Pilots Assn., Ontario, Canada; Booker T. Burley, Hartsfield Atlanta Int'l Airport, GA; William M. Carey, Underwriters Laboratories Inc., IL; Bob Casey, BDM International, VA; Robert L. Darwin, Dept. of the Navy, DC; B. V. Hewes, Airport Safety Services, GA; William D. Killen, Naval Facilities Engr. Command (18-F), VA; Joan M. Leedy, 3M Company, MN; Robert J. Manley, Int'l Federation of Airline Pilots, WA; Bertrand F. Ruggles, FAA Dept. of Transportation, DC; Mark T. Conroy, NFPA Staff Liaison.

This edition is a partial revision.

Technical Committee on Aircraft Rescue and Fire Fighting

John F. Rooney, *Chair*

Tucson, AZ

James F. O'Regan, *Vice Chair*
Westboro, MA

Edward B. (Ned) Aksim, Chubb Nat'l Foam, PA

Brian Boucher, Canadian Air Line Pilots Assn., Ontario, Canada
Rep. Canadian Air Line Pilots Assn.

Booker T. Burley, Hartsfield Atlanta Int'l Airport, GA

Robert L. Darwin, Dept. of the Navy - Fire Protection Div., DC

Robert J. Donahue, Massport, MA

B. V. Hewes, Airport Safety Services, GA

Paul O. Huston, Amerex Corp., AL
Rep. Fire Equipment Mfrs. Assn., Inc.

L. M. Krasner, Factory Mutual Research Corp., MA

Dan Lanzdorf, Oshkosh Truck Corp., WI

Thomas J. Lett, Albuquerque Fire & Safety Assoc. Inc., NM
Rep. NFPA Fire Service Section

D. Robin Maryon, Simon Gloster Saro Ltd., UK

John J. O'Sullivan, British Airways, UK

Davis R. Parsons, Los Angeles City Fire Dept., CA

Gaetan Perron, Dept. of Nat'l Defence, Ontario, Canada

Robert E. Reyff, U.S. Air Force, FL

Paul R. Robinson, Kennesaw, GA
Rep. Air Line Pilots Assn.

Bertrand F. Ruggles, FAA Dept. of Transportation, DC

Joseph L. Scheffey, Hughes Assoc. Inc., MD

John M. Schuster, 3M Co., MN

John X. Stefanki, John X. Stefanki, Inc., CA

William J. Wenzel, Voorheesville, NY
Rep. Walter Truck Corp.

Ronald O. Wikander, Lockheed Aeronautical Systems Co., GA

Larry E. Williams, Williams Training Assoc., AR

Richard Winnie, Emergency One, Inc., FL

Joseph A. Wright, DOT/FAA Technical Center, NJ
Rep. Atlantic City Int'l Airport, NJ

Alternates

Joan M. Leedy, 3M Co., MN
(Alt. to J. M. Schuster)

Dave Lenz, Oshkosh Truck Corp., WI
(Alt. to D. Lanzdorf)

Robert Maxwell, Dept. of Nat'l Defense, Ontario, Canada
(Alt. to G. Perron)

Thomas E. McMaster, Los Angeles City Fire Dept., CA
(Alt. to D. R. Parsons)

William E. Moore, U.S. Federal Aviation Admin., CO
(Alt. to B. F. Ruggles)

Bruce A. Warner, ICI Americas Inc., DE
(Alt. to P. O. Huston)

William S. Weeks, Air Line Pilots Assn., NC
(Alt. to P. R. Robinson)

Nonvoting

Bernard Brown, Civil Aviation Authority, UK

John E. Lodge, Lodge Fire Protection Consultancy Ltd., UK
(Member Emeritus)

Edward F. Mudrowsky, Nat'l Transportation Safety Board, DC

Committee Scope: This Committee shall have primary responsibility for the criteria for aircraft rescue and fire fighting services and equipment, procedures for handling aircraft fire emergencies, and for specialized vehicles used to perform these functions at airports with particular emphasis on saving lives and reducing injuries coincident with aircraft fires following impact or aircraft ground fires. This Committee shall also develop aircraft fire investigation procedures as an aid to accident prevention and the saving of lives in future aircraft accidents involving fire.

NFPA 403

Standard for Aircraft Rescue and Fire Fighting Services at Airports

1993 Edition

NOTICE: An asterisk (*) following the number or letter designating a paragraph indicates explanatory material on that paragraph in Appendix A.
Information on referenced publications can be found in Chapter 8 and Appendix B.

Chapter 1 Administration

1-1 Scope.

This standard contains the minimum requirements for aircraft rescue and fire fighting (ARFF) services at airports. Requirements for other airport fire protection services are not covered in this document.

1-2 Purpose.

1-2.1

This standard is prepared for the use and guidance of those charged with providing and maintaining aircraft rescue and fire fighting services at airports.

1-2.2

The principal objective of a rescue and fire fighting service is to save lives. For this reason, the provision of means of dealing with an aircraft accident or incident occurring at, or in the immediate vicinity of, an airport assumes primary importance because it is within this area that there are the greatest opportunities of saving lives. This must assume at all times the possibility of, and need for, extinguishing a fire that may occur either immediately following an aircraft accident or incident, or at any time during rescue operations.

1-2.3

The most important factors bearing on effective rescue in a survivable aircraft accident are: the training received, the effectiveness of the equipment, and the speed with which personnel and equipment designated for rescue and fire fighting purposes can be put to use.

1-3 Definitions.

For the purpose of this standard, the following terms shall have the meanings given below.

ARFF Personnel. Personnel actively engaged in the pursuit of rescue and fire fighting at the scene of an airport incident.

Actual Response Time. The total period of time measured from the time of an alarm until the first ARFF vehicle arrives at the scene of an aircraft accident and is in position to apply agent.

Aircraft Accident. An occurrence associated with the operation of an aircraft that takes place between the time any person boards the aircraft with the intention of flight and until all such persons have disembarked and in which any person suffers death or serious injury or in which the aircraft receives substantial damage.

Aircraft Fire Fighting. The control or extinguishment of fire adjacent to or involving an aircraft following ground accidents/incidents. Aircraft fire fighting does not include the control or extinguishment of airborne fires in aircraft.

Aircraft Incident. An occurrence, other than an accident, associated with the operation of an aircraft, that affects or could affect continued safe operation if not corrected. An incident does not result in serious injury to persons or substantial damage to the aircraft.

Aircraft Rescue. The fire fighting action taken to prevent, control, or extinguish fire involving, or adjacent to, an aircraft for the purpose of providing maximum fuselage integrity and escape area for its occupants. Rescue and fire fighting personnel, to the extent possible, will assist in evacuation of the aircraft using normal and emergency means of egress. Additionally, rescue and fire fighting personnel will, by whatever means necessary, and to the extent possible, enter the aircraft and provide all possible assistance in the evacuation of the occupants.

Airport Air Traffic Control. A service established to provide air and ground traffic control for airports.

Airport Fire Chief. The individual normally having operational control over the airport's rescue and fire fighting personnel and equipment, or a designated appointee.

Airport Fire Department Personnel. Personnel under the operational jurisdiction of the chief of the airport fire department assigned to aircraft rescue and fire fighting.

Airport Manager. The individual having managerial responsibility for the operation and safety of an airport. The manager may have administrative control over aircraft rescue and fire fighting services, but normally does not exercise authority over operational fire and rescue matters.

Approved.* Acceptable to the "authority having jurisdiction."

Authority Having Jurisdiction.* The "authority having jurisdiction" is the organization, office or individual responsible for "approving" equipment, an installation or a procedure.

Critical Rescue and Fire Fighting Access Area. The rectangular area surrounding a runway within which aircraft movements can be expected to occur on airports. Its width extends 500 ft (150 m) from each side of the runway centerline, and its length is 3,300 ft (1,000 m) beyond each runway threshold.

Fixed Base Operator (FBO). An enterprise based on an airport that provides storage, maintenance, or service for aircraft operators.

Flight Service Station (FSS). An air traffic facility that briefs pilots, processes, and monitors flight plans and provides in-flight advisories.

Foam. An aggregation of small bubbles used to form an air-excluding, vapor-suppressing blanket over the surface of a flammable liquid fuel.

Foam, Alcohol-Resistant. Used for fighting fires involving water-soluble materials or fuels that are destructive to other types of foam. Some alcohol-resistant foams may be capable of forming a vapor-suppressing, aqueous film on the surface of hydrocarbon fuels.

Foam, Aqueous Film Forming (AFFF). A concentrated aqueous solution of one or more hydrocarbon and/or fluorochemical surfactants that forms a foam capable of producing a vapor-suppressing, aqueous film on the surface of hydrocarbon fuels. The foam produced from AFFF concentrates is dry chemical compatible and is therefore suitable for use in combination with that agent.

Foam Concentrate. A concentrated liquid foaming agent that is mixed with water and air in designated proportions to form foam.

Foam, Film Forming Fluoroprotein (FFFP). A protein-based foam concentrate incorporating fluorinated surfactants that forms a foam capable of producing a vapor-suppressing, aqueous film on the surface of hydrocarbon fuels. This foam may show an acceptable level of compatibility to dry chemicals and may be suitable for use with those agents.

Foam, Fluoroprotein (FP). A protein-based foam concentrate with added fluorochemical surfactants that forms a foam showing a measurable degree of compatibility with dry chemical extinguishing agents and an increase in tolerance to contamination by fuel.

Foam, Protein (P). A protein-based foam concentrate that is stabilized with metal salts to make a fire-resistant foam blanket.

Foam Solution. The solution that results when foam concentrate and water are mixed in designated proportions prior to aerating to form foam.

Fuselage. The main body of an aircraft.

International Civil Aviation Organization (ICAO). An international body charged with matters dealing with the development, coordination, and preservation of international civil aviation.

May. This term is used to state a permissive use, or an alternative method to a specified requirement.

Movement Area. Those parts of the airport used for taxiing, takeoff, and landing of aircraft, exclusive of parking areas.

Mutual Aid. Reciprocal assistance by emergency services under a prearranged plan.

Rapid Response Area (RRA).* A rectangle that includes the runway and the surrounding area extending to but not beyond the airport property line. Its width extends 500 ft (152 m) outward from each side of the runway centerline, and its length is 1650 ft (500 m) beyond each runway end. (*See Figure A-1-3.*)

Shall. Indicates a mandatory requirement.

Should. This term, as used in the Appendix, indicates a recommendation or that which is advised but not required.

Table-Top Training. A workshop-style of training involving a realistic emergency scenario and requiring problem-solving participation by personnel responsible for management and support at emergencies.

Chapter 2 Organization of Aircraft Rescue and Fire Fighting (ARFF) Services

2-1 Administrative Responsibilities.

2-1.1

The airport management shall be responsible for the provisions of ARFF services on the airport.

2-1.2

Regardless of the functional control of ARFF services on the airport, a high degree of mutual aid shall be prearranged between such services on airports and any off-airport fire or rescue agencies serving the environs of the airport.

2-1.3

The aircraft owner/operator shall ensure that provisions have been made for the security of the aircraft until such time as a legally appointed accident investigation authority assumes responsibility. The airport manager or authority having jurisdiction may assist or assume the authority in the absence of the aircraft owner/operator.

2-2 Emergency Preparedness.

2-2.1*

Airports shall prepare a disaster plan, taking into account airport emergency services and mutual aid services available in the event of a disaster.

2-2.2

Full-scale airport disaster plans shall be tested at least every other year. In addition, table-top training shall be conducted at least annually.

2-3 Categorizing Airports for ARFF Services.

2-3.1*

The authority having jurisdiction shall determine the level of protection based on the largest aircraft scheduled into the airport. Airports shall be categorized for ARFF services in accordance with Table 2-3.1.

Table 2-3.1 Airport Category by Overall Length and Width of Aircraft

Airport Category U.S.			Overall Length of Aircraft up to but Not Including		Maximum Exterior Width up to but Not Including	
NFPA	FAA	ICAO	Feet	Meters	Feet	Meters
1	GA-1	1	30	9	6.6	2
2	GA-1	2	39	12	6.6	2
3	GA-2	3	59	18	9.8	3
4	A	4	78	24	13.0	4
5	A	5	90	28	13.0	4
6	B	6	126	39	16.4	5
7	C	7	160	49	16.4	5
8	D	8	200	61	23.0	7
9	E	9	250	76	23.0	7
10			300	91	25.0	8

2-3.2*

The airport category for a given aircraft shall be based on the overall length of the aircraft or the fuselage width. If, after selecting the category appropriate to the aircraft's overall length, the aircraft's fuselage width is greater than the maximum width given in Table 2-3.1, then the category for that aircraft shall be the next one higher.

Chapter 3 Extinguishing Agents

3-1 Primary Agents.

3-1.1*

One or more of the following types of primary agents shall be used for aircraft fire fighting involving hydrocarbon fuels.

(a) Aqueous film forming foams (AFFF)

(b) Fluoroprotein foam (FP) or film forming fluoroprotein foam (FFFP)

(c) Protein foam (P).

3-1.2*

All foam concentrates shall be approved or listed based on the following performance test requirements.

3-1.2.1* Aqueous film forming foam agents shall meet the applicable fire extinguishment and burnback performance requirements for the 50 sq ft (4.6 m^2) fire test in accordance with Military Specification MIL-F-24385.

3-1.2.2 Film forming fluoroprotein foam (FFFP), protein foam (P), and fluoroprotein foam (FP) agents shall meet the applicable fire extinguishment and burnback performance requirements of Underwriters Laboratories Inc. Standard UL-162 (Type 3 application).

3-1.2.3 Any primary agent used at the minimum quantities and discharge rates for AFFF in Tables 3-3.1(a) and 3-3.1(b) shall meet the applicable fire extinguishment and burnback performance requirements of 3-1.2.1.

3-2 Complementary Agents.

Either one or both of the following complementary agents shall be available for aircraft fire fighting:

(a)* Potassium bicarbonate dry chemical

(b)* Halon 1211.

3-3 Quantity of Agents.

3-3.1

The minimum amounts of water for foam production, and the minimum amounts of complementary agents necessary shall be as specified in Tables 3-3.1(a) or 3-3.1(b) based on the system of categorizing airports listed in Table 2-3.1.

Table 3-3.1(a) Minimum Extinguishing Agent Quantities and Discharge Rates

	AFFF		Fluoroprotein or Film Forming Fluoroprotein Foam		Protein Foam		Potassium Bicarbonate		Halon 1211	
Airport Category	Water U.S. Gallons	Discharge Rate gpm	Water U.S Gallons	Discharge Rate gpm	Water U.S. Gallons	Discharge Rate gpm	Pounds	Discharge Rate lbs/sec	Pounds	Discharge Rate lb/sec
1	60	60	80	75	90	85	100	5	100	5
2	185	130	225	180	240	195	200	5	200	5
3	615	230	725	310	760	335	300	5	300	5
4	1200	390	1420	530	1500	575	300	5	300	5
5	2700	825	3250	1135	3450	1230	450	5	450	5
6	3450	1100	4250	1480	4550	1620	450	5	450	5
7	4550	1440	5750	1970	6150	2150	450	5	450	5
8	7300	1900	9100	2600	10850	2845	900	10	900	10
9	9000	2400	11750	3300	12200	3480	900	10	900	10
10	12200	3100	16300	4100	18300	4600	900	10	900	10

Table 3-3.1(b) Minimum Extinguishing Agent Quantities and Discharge Rates

Airport Category	AFFF Water Liters	AFFF Discharge Liters/min	Fluoroprotein or Film Forming Fluoroprotein Foam Water Liters	Fluoroprotein or Film Forming Fluoroprotein Foam Discharge Liters/min	Protein Foam Water Liters	Protein Foam Discharge Liters/min	Potassium Bicarbonate kg	Potassium Bicarbonate Discharge Rate kg/min	Halon 1211 kg	Halon 1211 Discharge Rate kg/sec
1	250	225	300	290	330	320	45	2.25	45	2.25
2	650	500	850	680	925	745	90	2.25	90	2.25
3	2300	800	2700	1165	2900	1270	135	2.25	135	2.25
4	4500	1500	5400	2000	5700	2180	135	2.25	135	2.25
5	10200	3000	12300	4300	13000	4650	205	2.25	205	2.25
6	13000	4000	16100	5600	17200	6138	205	2.25	205	2.25
7	17200	5500	21800	7450	23300	8135	205	2.25	205	2.25
8	27600	7000	29700	9850	31600	10770	410	4.5	410	4.5
9	34000	9000	44500	12500	46200	13660	410	4.5	410	4.5
10	46200	11700	61700	15500	69300	17400	410	4.5	410	4.5

3-3.2

Sufficient foam concentrate shall be provided to proportion, at the prescribed percentage of foam concentrate to water, into double the quantity of water specified in Table 3-3.1(a) or 3-3.1(b).

3-3.3*

Water equal to 100 percent of that required by 3-3.1 shall be available to replenish the primary fire fighting vehicle(s).

3-4 Compatibility of Agents.

3-4.1*

Chemical compatibility shall be ensured between foam and complementary agents where used simultaneously or consecutively.

3-5 Combustible Metal Agents.

3-5.1*

Extinguishing agents for combustible metal fires shall be provided in portable fire extinguishers that are rated for Class D fires in accordance with Section 1-4 of NFPA 10, *Standard for Portable Fire Extinguishers*. At least one nominal 20-lb (9.1-kg) extinguisher shall be carried on each vehicle specified in Table 4-1.1.

3-6 Agent Discharge Capabilities.

3-6.1

The discharge capabilities of extinguishing agents shall not be less than the rates specified in Table 3-3.1(a) or 3-3.1(b), and Sections 2-15.6, 3-13.9, and 4-13.9, as applicable, of NFPA 414, *Standard for Aircraft Rescue and Fire Fighting Vehicles*.

3-6.2

Other than at Category 1, 2, and 3 airports, where the handline nozzles can be used, the discharge rates for foam shall be met using only the ARFF vehicle turret(s).

Chapter 4 Aircraft Rescue and Fire Fighting (ARFF) Vehicles

4-1 Rescue and Fire Fighting Vehicles.

4-1.1*

The minimum number of ARFF vehicles provided at each airport shall be as specified in Table 4-1.1.

Table 4-1.1 Minimum Number of ARFF Vehicles

Airport Category	1	2	3	4	5	6	7	8	9	10
Number of Vehicles	1	1	1	1	2	2	3	3	4	4

4-1.2*

ARFF vehicles shall be constructed to comply with the provisions of NFPA 414, *Standard for Aircraft Rescue and Fire Fighting Vehicles*, and Table 3-3.1(a) or 3-3.1(b).

4-1.3

Consideration shall be given to the provision of an additional vehicle or vehicles in order that minimum requirements are maintained during periods when a vehicle is out of service.

4-1.4

All foam-producing ARFF vehicles shall be tested at least annually in accordance with NFPA 412, *Standard for Evaluating Aircraft Rescue and Fire Fighting Foam Equipment*.

4-2* Tools and Equipment.

Vehicles shall be provided with tools and equipment to effectively support rescue and fire fighting operations.

Chapter 5 Airport Emergency Communications

5-1 Communications and Alarms.

5-1.1

Airport ARFF services communications shall have a capability that is consistent with the airport's operational needs.

5-1.2*

The operational communications system shall provide a primary and, where necessary, an alternate effective means for direct communication between the following, as applicable:

(a) The alerting authority such as the control tower or flight service station, airport manager, fixed-base operator, or airline office and the airport ARFF service;

(b) Air traffic control tower or flight service station and ARFF vehicles enroute to an aircraft emergency or at the accident/incident site;

(c) The fire department alarm room and ARFF vehicles at the accident/incident site;

(d) The airport ARFF services and appropriate mutual aid organizations located on or off the airport, including an alert procedure for all auxiliary personnel expected to participate; and

(e) The ARFF vehicles.

5-1.3

To ensure that the communications system is operational under a variety of airport emergency conditions, provisions shall be made for an emergency standby power source or alternate backup communication system.

5-1.4

A preventive maintenance program shall be carried on to keep all communications equipment in a fully serviceable condition.

5-1.5

The functional performance of all communications systems shall be tested at intervals not exceeding 24 hours.

Chapter 6 ARFF Personnel and Protective Clothing

6-1 Personnel.

6-1.1

A person shall be appointed to direct the airport ARFF services. The responsibilities of this person shall include overall administrative supervision of the organization, effective training of personnel, and operational control of emergencies involving aircraft within the airport jurisdiction.

6-1.2

During flight operations, sufficient trained personnel shall be readily available to staff the rescue and fire fighting vehicles and to perform fire fighting and rescue operations. These trained personnel shall be deployed in a way that ensures that minimum response times can be achieved and that continuous agent application at the appropriate rate can be fully maintained.

6-1.3

Responding units shall include personnel trained and equipped for cabin interior fire fighting.

6-1.4*

All ARFF personnel shall meet the requirements of NFPA 1003, *Standard for Airport Fire Fighter Professional Qualifications*.

6-1.5

All ARFF and other authorized personnel shall be given suitable uniforms or identifying insignia to prevent any misunderstanding as to their right to be in the fire area or the aircraft movement area of an airport during an emergency.

6-2 Protective Clothing.

6-2.1*

Approved protective clothing and equipment including protective coat, protective trousers, helmet, gloves, and self-contained breathing apparatus (SCBA) shall be provided, maintained, and readily available for use by all ARFF personnel.

6-2.2*

SCBA for ARFF personnel shall meet the requirements of NFPA 1981, *Standard on Open-Circuit Self-Contained Breathing Apparatus for Fire Fighters*.

6-2.3

Station/work uniforms worn by ARFF personnel shall meet the requirements of NFPA 1975, *Standard on Station/Work Uniforms for Fire Fighters*.

6-2.4

Other than ARFF vehicle driver/operators, all ARFF personnel engaged in any rescue or fire fighting operation shall wear complete protective clothing including SCBA and shall not remove any protective clothing or SCBA until they are in a safe area and so directed by the officer in charge.

Chapter 7 Airport Fire Station Location and Response Capability

7-1 Siting and Response.

7-1.1*

ARFF vehicles shall be garaged at one or more strategic locations as needed to meet required response times.

7-1.2*

Emergency equipment shall have immediate and direct access to critical aircraft movement areas and the capability of reaching all points within the Rapid Response Area (RRA) in the time specified. Therefore, the location of the airport fire station shall be based on minimizing response time to aircraft accident and incident high-hazard areas. Locating the airport fire station for structural fire fighting utility is of secondary importance.

7-1.3*

The demonstrated response time of the first responding vehicle to reach any point on the operational runway shall be 2 minutes or less and to any point remaining within the on-airport portion of the rapid response area shall be no more than $2^1/_2$ minutes, both in optimum conditions of visibility and surface conditions. Other ARFF vehicles necessary to achieve the agent discharge rate listed in Table 3-3.1(a) or 3-3.1(b) shall arrive at intervals not exceeding 30 seconds.

Chapter 8 Referenced Publications

8-1

The following documents or portions thereof are referenced within this standard and shall be

considered part of the requirements of this document. The edition indicated for each reference is the current edition as of the NFPA issuance of this document.

8-1.1 NFPA Publications.

National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.

NFPA 10, *Standard for Portable Fire Extinguishers*, 1990 edition.

NFPA 412, *Standard for Evaluating Aircraft Rescue and Fire Fighting Foam Equipment*, 1993 edition.

NFPA 414, *Standard for Aircraft Rescue and Fire Fighting Vehicles*, 1990 edition.

NFPA 1003, *Standard for Airport Fire Fighter Professional Qualifications*, 1987 edition.

NFPA 1975, *Standard on Station/Work Uniforms for Fire Fighters*, 1990 edition.

NFPA 1981, *Standard on Open-Circuit Self-Contained Breathing Apparatus for Fire Fighters*, 1992 edition.

8-1.2 Other Publications.

Fire Extinguishing Agent, Aqueous Film-Forming Foam (AFFF), Liquid Concentrate, for Fresh and Sea Water, Revision F, January 7, 1992, U.S. Military Specification MIL-F-24385, Naval Publications and Forms Center, 5801 Tabor Avenue, Philadelphia, PA 19120.

Standard for Foam Equipment and Liquid Concentrates, 6th edition, March 7, 1989, Underwriters Laboratories Inc., Standard UL-162.

Appendix A Explanatory Material

This Appendix is not a part of the requirements of this NFPA document but is included for information purposes only.

A-1-3 Approved.

The National Fire Protection Association does not approve, inspect or certify any installations, procedures, equipment, or materials nor does it approve or evaluate testing laboratories. In determining the acceptability of installations or procedures, equipment or materials, the authority having jurisdiction may base acceptance on compliance with NFPA or other appropriate standards. In the absence of such standards, said authority may require evidence of proper installation, procedure or use. The authority having jurisdiction may also refer to the listings or labeling practices of an organization concerned with product evaluations which is in a position to determine compliance with appropriate standards for the current production of listed items.

A-1-3 Authority Having Jurisdiction.

The phrase “authority having jurisdiction” is used in NFPA documents in a broad manner since jurisdictions and “approval” agencies vary as do their responsibilities. Where public safety is primary, the “authority having jurisdiction” may be a federal, state, local or other regional department or individual such as a fire chief, fire marshal, chief of a fire prevention bureau, labor department, health department, building official, electrical inspector, or others having statutory authority. For insurance purposes, an insurance inspection department, rating bureau, or other insurance company representative may be the “authority having jurisdiction.” In many circumstances the property owner or his designated agent assumes the role of the “authority having jurisdiction”; at government installations, the commanding officer or departmental official may be the “authority having jurisdiction.”

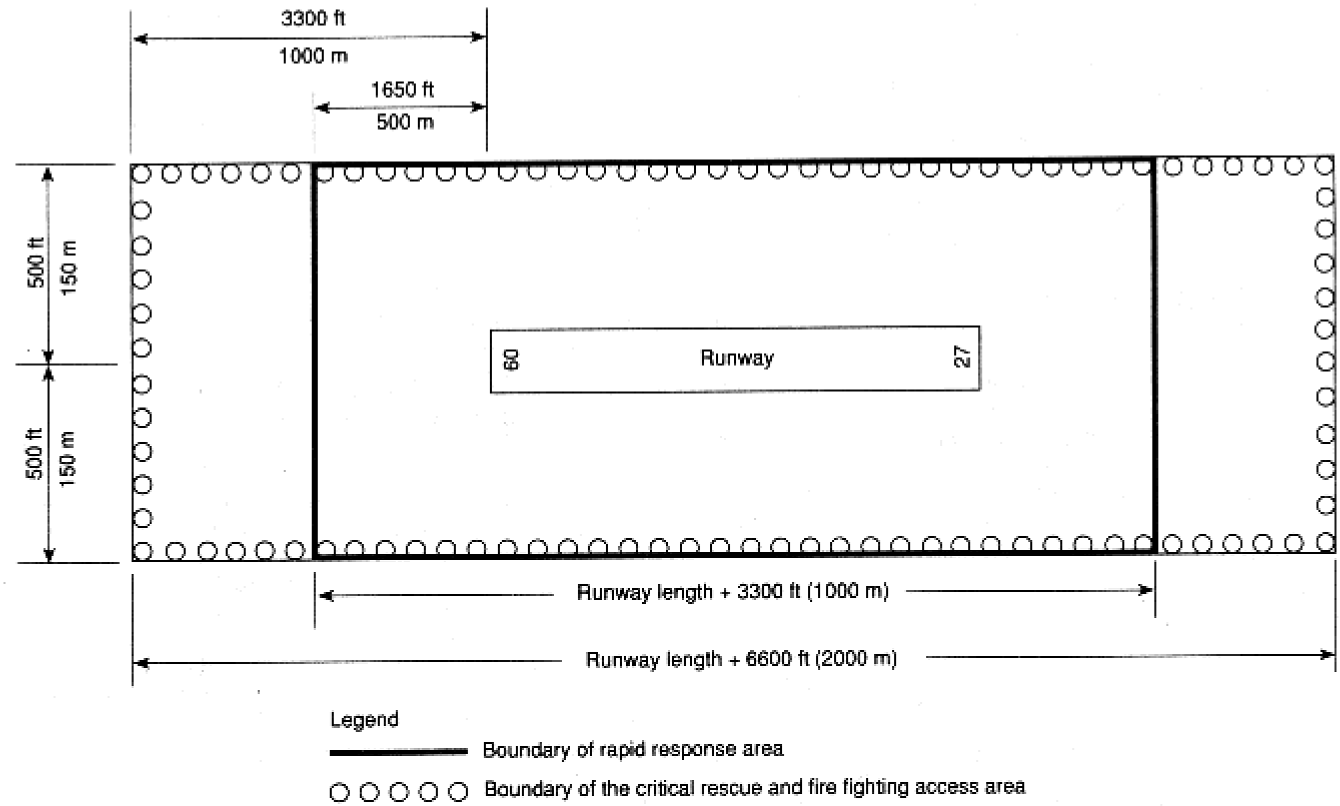


Figure A-1-3 Response and access areas.

A-1-3 Rapid Response Area (RRA).

Approximately 85 percent of the accidents as historically recorded in the CRFFAA occurred within the boundary of the RRA and response time to the on-airport portion of the RRA should meet the times specified in 7-1.3. (*See Figure A-1-3.*)

A-2-2.1

See NFPA 424M, *Manual for Airport/Community Emergency Planning*, for comprehensive guidance.

A-2-3.1 Background.

Area Concept. The first meeting of the Rescue and Fire Fighting Panel (RFFP-I) was convened by the International Civil Aviation Organization (ICAO) in Montreal, Canada, from March 10 to 20, 1970.

At that time, the method contained in Annex 14, Attachment C (5th edition) for the determination of the level of protection (agent quantities and number of vehicles) to be provided at airports for fixed wing aircraft was based on the fuel load and passenger capacity of the aircraft. As a result of correspondence exchanged among the Panel members there was general agreement that a new or revised method for specifying the quantity of extinguishing agents and rescue equipment to be provided was needed.

The Panel unanimously agreed that the concept for determining the level of protection should be the “critical area.” This was an area to be protected in any post-accident situation that would permit the safe evacuation of the aircraft occupants. The purpose of the critical area concept was not to define fire attack procedures. Instead, it was to serve as the basis for calculating the quantities of extinguishing agents necessary to achieve protection within an acceptable period of time.

The Panel also unanimously agreed that the critical area should be a rectangle having as one dimension the length of the fuselage. The logic being that passenger capacity was related to length. However, a wide division of opinion existed as to what width should be used. The RFF Panel’s report documents five proposed means of defining the width of the critical area.

It was finally agreed that there was no single system that could be used to express the area to be protected for all sizes of aircraft. In the end, the Panel agreed that the critical area should be a rectangle, having as one dimension the overall length of the aircraft and as the other dimension the overall length of the aircraft for aircraft with wing spans of less than 30 m (100 ft) and to be 30 m (100 ft) for aircraft with wing spans of 30 m (100 ft) or more. A standard fuselage width of 6 m (20 ft) was assumed. Using this approach, the aircraft in service at that time were grouped into a series of eight categories. Beginning with category one, each successive category represented a logical progression in aircraft length.[1]

[1]Hewes, B. V., Chairman, “Report of the First Meeting of the ICAO Rescue and Fire Fighting Panel (RFFP-I),” March 10-20, 1970, Montreal, Canada, WP/28, Section 2.1 Area Concept, p. 2-1.

The concept of using graduated aircraft categories as a means of assessing fire protection needs has survived to the present time with only minor revisions to reflect changes in the operating aircraft fleet. This general concept has been adopted worldwide by both consensus standard writing organizations and national regulatory authorities.

By correspondence following RFFP-I, the members agreed that the use of the area concept for determining the level of fire fighting agents and equipment needed to combat an aircraft accident fire was based on the facts that:

(a) the quantity of agent necessary to control or cover the fire area could be relatively accurately determined; and

(b) the rate of application of the agents to control the fire in the most effective time period could also be determined.

Hence, when RFFP-II convened in 1972 the Panel confirmed the critical area concept where one dimension of the area would be the length of the aircraft. However, there was no consensus as to length of the other side. In addition, the Panel concluded that there was a need to distinguish between the “theoretical critical area” within which it might be necessary to control a fire and a “practical critical area” that was representative of actual aircraft accident conditions. Although the Panel had not agreed on the dimensions, it did agree that the theoretical critical area should be defined as follows:

Theoretical critical area: The theoretical area adjacent to an aircraft in which fire must be controlled for the purpose of ensuring temporary fuselage integrity and providing an escape area for its occupants.

The RFFP-II had benefit of large test fire experiments conducted by a member country aimed at estimating the size of the theoretical critical fire area.[2] That study paid particular attention to the width on each side of the fuselage, which would have to be secured to protect the aircraft's skin from melting under severe fire conditions. On the basis of the data presented in that report, the Panel agreed that the theoretical critical area should be a rectangle having as one dimension the overall length of the aircraft, and as the other dimension:

(a) for aircraft with an overall length of less than 20 m (65 ft), 12 m (40 ft) plus the width of the fuselage; and

(b) for aircraft with an overall length of 20 m (65 ft) or more, 30 m (100 ft) plus the width of the fuselage.[3]

The theoretical critical area serves only as a means for categorizing aircraft in terms of the magnitude of the potential fire hazard in which they may become involved. It is not intended to represent the average, maximum, or minimum spill fire size associated with a particular aircraft. The original formula for the maximum theoretical critical area, as presented in the RFFP-II report, was given as follows:[4]

[2]Geyer, G. B., "Evaluation of Aircraft Ground Fire Fighting Agents and Techniques," Report No. AGFSRS-71-1, Tri-Service Systems Program Office Aircraft Ground Fire Suppression and Rescue, Wright-Patterson AFB, OH 45433, February 1972. NTIS No. AD 741 881, Section VIII, p. 172ff.

[3]Harley, R. A., Chairman, "Report of the Second Meeting of the ICAO Rescue and Fire Fighting Panel (RFFP-II)," June 5-16, 1972, Montreal, Canada, Section 3.1 and 3.2, p. 3-1f.

[4]Ibid., Recommendation 3/2 Guidance Material on the Critical Area Concept, p. 3-16.

$A_T = L \times (30 + w)$ where $L > 20$ m,

or

$A_T = L \times (100 + w)$ where $L > 65$ ft, and

$A_T = L \times (12 + w)$ where $L < 20$ m,

or

$A_T = L \times (40 + w)$ where $L < 65$ ft

where

L = the overall length of the aircraft,

w = the width of the aircraft fuselage, and

A_T = the theoretical critical area (TCA).

The data analyzed by RFFP-II in its effort to respond to the issue of TCA versus practical critical area (PCA) appeared to indicate that the PCA was approximately two-thirds of the TCA. This had been verified by a study conducted by one of the member countries of actual spill fire sizes and aircraft accidents.[5] Another analysis of aircraft rescue and fire fighting operation had not included the study of the PCA as compared to the TCA.[6] However, that study did compare the actual amount of water used for foam at those accidents with the amounts recommended by RFFP-I and it was found that out of 106 accidents for which this information was available, in 99 cases or 93 percent the amounts recommended by the Panel were in excess of those required in the actual aircraft accident. In light of the above, the Panel decided to use two-thirds of the TCA as the PCA.[7] See Figure A-2-3.1(a) for a graphic display of this concept. The formula for the PCA developed by RFFP-II for fixed-wing aircraft can be expressed as:

$$PCA = (0.67) \times (TCA).$$

Control Time. After defining the critical area to be protected and developing a system of fire protection categories, RFFP-I turned its attention to the issues of discharge rates and the extinguishing agents to be applied to the critical area. The Panel concluded that fire control time and fire extinguishment time within the critical area should be considered individually and defined as follows:

Control time is the time required from the arrival of the first fire fighting vehicle to the time the initial intensity of the fire is reduced by 90 percent.

Extinguishment time is the time required from arrival of the first fire fighting vehicle to the time the fire is completely extinguished.[8]

RFFP-II confirmed these definitions and, based on an analysis of accident data furnished by member countries, it considered that the equipment and techniques to be used should be capable of controlling the fire in the PCA in 1 minute.[9] This concept not only survived to the present time, but it has, with minor revisions from time to time to update changes in the operating aircraft fleet, been adopted worldwide by both consensus standards-making organizations and national regulatory authorities.

RFFP-II was unable to identify a recommended time period for the extinguishment time. This was due to the numerous variables involved at each aircraft accident such as the size of the aircraft, area of fire, and three-dimensional fires.[9]

[5] Ansart, F., Analysis of Reports of Accidents No. 1 to 217 Filed with ICAO as of March 1970, Unpublished meeting records of reference material used by RFFP-II.

[6] Harley, op. cit., Section 1.2, Review of Reports, p. 1-1.

[7] Ibid., Section 3.3, Practical Critical Area, p. 3-3.

[8] Hewes, op. cit., Section 2.2, Control Time, p. 2-2.

[9] Harley, op. cit., Section 3.5, Control and Extinguishment Time, p. 3-4.

Discharge Rate. At RFFP-I, the Panel agreed that discharge rates should be designed to achieve the lowest possible fire control time that is consistent with the objective of preventing the fire from melting through the fuselage or causing an explosion of the fuel tanks. The Panel also agreed that the equipment and techniques to be used should be capable of controlling the fire in the critical area in 1 minute and of extinguishing the fire within another minute. Using available fire extinguishment test data based on protein foam, the Panel concluded that for a single agent attack an application rate of 8.2 (L/min)/m^2 (0.2 U.S. gpm/ft^2) for 2 minutes would be sufficient to meet the fire control and fire extinguishment time requirements. The Panel also agreed that when dual agent attack techniques were used (foam and dry chemical, CO_2, or a halocarbon), a reduced application rate could be used. A minimum of 6.1 (L/min)/m^2 (0.15 U.S. gpm/ft^2) was recommended.

Based on the consideration that the lighter construction of small aircraft increased their vulnerability to fire penetration, the Panel also recommended that the same discharge rates be used for small aircraft.

All of the discussions and recommendations at RFFP-I were based on the performance of protein foam only. The Panel's report recognized the existence of both fluoroprotein and aqueous film forming foams and indicated that some member countries were starting to use them. However, the Panel generally agreed that there was insufficient documentation of performance upon which to base recommendations. The report also indicated a general understanding among Panel members that the suitability of other agents and their relationship with protein foam would be considered later.[10]

At RFFP-II, the Panel confirmed the application rate for protein foam recommended by RFFP-I and agreed that an application rate of 5.3 (L/min)m^2 (0.13 U.S. gpm/ft^2) for aqueous film forming foam was suitable. The Panel could not agree on a suitable recommendation for fluoroprotein due to the wide variety of foams. However, it did recognize them as useful aircraft fuel fire fighting foams and left the application rate to the authority having jurisdiction; to be based on test data for the individual foams.[11]

Quantities of Agent to Be Provided. By multiplying the TCA corresponding to the upper limit of the airport category times the recommended protein foam application rate, times a factor of two for the recommended discharge time, RFFP-I produced a table of recommended water quantities for foam production. The table also included recommended weights for complementary agents and the recommended discharge rates for both single and dual agent attack for eight airport categories.[12]

[10]Hewes, op. cit., Section 2.3, Discharge Rate, p. 2-2.

[11]Harley, op. cit., Sections 3.6, Application Rate & 3.7 Discharge Rate, p. 3-4f.

[12]Hewes, op. cit., Section 2.4, Quantities of Agent, p. 2-3. and Table C-2, Minimum Amounts of Extinguishing Agents, p. 2-17.

At RFFP-II, the Panel agreed that when determining the amounts of extinguishing agents to be provided, the amounts required to control and to extinguish a fire should be determined separately. The quantities were named and defined as follows:

Quantity Q_1. The quantity required to obtain a 1-minute control time in the PCA.

The formula for the water required for control in the PCA (Q_1) can be expressed as:

$$Q_1 = PCA \times R \times T$$

where

PCA = the practical critical area,

R = the rate of application for the specific foam, and

T = time of application.

Quantity Q_2. The quantity required for continued control of the fire after the first minute or for complete extinguishment of the fire or for both.

The Panel concluded that the amount of water required for Q_2 could not be calculated exactly, as it depended on a number of variables. Those variables considered of primary importance by the Panel were:

(a) maximum gross weight,

(b) maximum passenger capacity,

(c) maximum fuel load, and

(d) previous experience (analysis of aircraft rescue and fire fighting operations).

These factors were used by RFFP-II to generate Q_2 values for each airport category where $Q_2 = f \times Q_1$. The values of f ranged from 3 percent for Category 1 airports through 170 percent for Category 8 airports.[13]

13Harley, op. cit., Recommendation 3/2 Guidance Material on the Critical Area Concept, p. 3-16 ff.

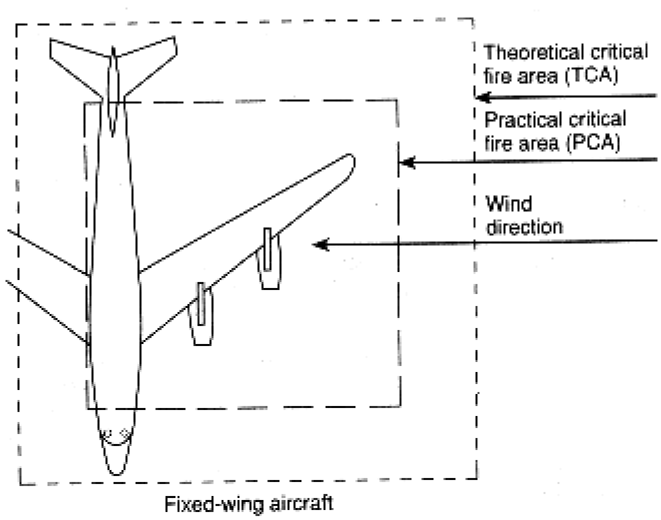


Figure A-2-3.1(a) Theoretical critical fire area (TCA) relative to practical critical fire area (PCA).

Today's Situation:

The basic concepts developed by the ICAO RFFPs are still considered valid. However, the variables mentioned above that are used to develop the f factor for Q_2 have been refined over time and are now expressed as follows:

(a) *Aircraft Size.* Aircraft size reflects the potential level of risk. This risk factor is a composite of the passenger load, the potential internal fire load, flammable liquid fuel capacity, and the fuselage length and width. Careful consideration of all these factors allows the identification of a meaningful operational objective, i.e., the area to be rendered fire-free (controlled or extinguished).

(b) *Relative Effectiveness of Agent Selected.* This is accounted for by the specific application rate identified for each of the common generic foam concentrate types.

(c) *Time Required to Achieve PCA Fire Control.* Information from reliable large-scale fire tests, empirical data from a wide variety of sources, and field experience worldwide indicates that 1 minute is both a reasonable and a necessary operational objective.

(d) *Time Required to Maintain the Controlled Area Fire-Free or to Extinguish the Fire.* An operational objective that provides a safety factor for the initial fire attack on the PCA while waiting for the arrival of backup support or to complete extinguishment of remaining fires outside the PCA.

The quantity of water for foam production required for 1 minute fire control of the PCA is still referred to as Q_1. However, data collected in the ensuing years now permits us to specify the required application rates for three generic foam types needed to extinguish fire in one square meter or one square foot of the PCA as follows:

(a) AFFF = 5.5 (L/min)/m^2 or 0.13 gpm/ft^2

(b) FP = 7.5 (L/min)/m^2 or 0.18 gpm/ft^2

(c) PF = 8.2 (L/min)/m^2 or 0.20 gpm/ft^2.

Over time the changes in aircraft size factor have required revisions to the values of both Q_1 and Q_2 and the introduction of a third component, Q_3, which make up the total quantity of water (Q) required for the production of foam.

For example, Q_1 changes as a function of the accepted foam application rates and the size of the operational aircraft common to the various airport categories. And, since Q_2 is a function of Q_1, it too is impacted by changes in aircraft size and requires revision from time to time to accurately reflect the changes in the operational aircraft fleet.

The operational significance of the components making up Q is substantial in that Q relates to both the specific quantities of fire suppression agents required to control fire in the PCA and to the requirement that the specified quantity of agent be applied to the PCA within a time frame of 1 minute. In turn, Q_2 relates to the need to have sufficient fire suppression agents available to maintain conditions that do not pose a threat to life in the PCA until such time as rescue operations are completed. The secondary role of Q_2 is to extinguish all fires in and peripheral to the PCA.

The development of the requirement for these two quantities of water is based on exterior aircraft fuel spill fire control parameters. Information from actual incidents in recent years has shown that with increased aircraft crash worthiness, water for interior fire fighting operations is also necessary. This quantity of water, called Q_3, is based on the need for hand lines to be used for interior fire fighting. Hence, the total quantity of water (Q) is now defined as follows:

$$Q = Q_1 + Q_2 + Q_3$$

where

Q_1 = water requirement for control of PCA,

Q_2 = water requirement to maintain control or extinguish the remaining fire or both, and

Q_3 = water requirement for interior fire fighting.

(*See Figure A-2-3.1(b)*.)

The method for calculating the values for each component of Q are presented below.

(1) $Q_1 = PCA \times R \times T$

where

PCA = (0.67) × TCA, TCA = L × (K + W), and L = length of aircraft;

W = width of fuselage,

R = application rate of selected agent,

T = time of application (1 minute), and

K = values shown below.

Feet	**Meters**
K = 39 where L = less than 39	K = 12 where L = less than 12
= 46 where L = 39 up to but not including 59	= 14 where L = 12 up to but not including 18
= 56 where L = 59 up to but not including 79	= 17 where L = 18 up to but not including 24
= 98 where L = 79 and over	= 30 where L = 24 and over

(2) The current values of Q_2 as a percentage of Q have been determined to be:

Airport Category	**Q_2% Q_1**	**Airport Category**	**Q_2% Q_1**
1	0	6	100
2	27	7	129
3	30	8	152
4	58	9	170
5	75	10	190

(3) The values of Q_3 are based on accepted water flow requirements for the type of fire fighting operations to be experienced when combating an interior aircraft fire. They are determined as follows:

Airport Category	**Q_3 Equals (U.S. gal)**
1	0

2	0
3	60 gpm × 5 min = 300 gal
4	60 gpm × 10 min = 600 gal
5	125 gpm × 10 min = 1250 gal
6	125 gpm × 10 min = 1250 gal
7	125 gpm × 10 min = 1250 gal
8	250 gpm × 10 min = 2500 gal
9	250 gpm × 10 min = 2500 gal
10	250 gpm × 10 min = 2500 gal

Sample Calculation Using Airport Category 4 and AFFF Foam:

$TCA = L \times (K + W)$

$= 68.5 \times (56 + 11.4) = 4617\ ft^2$

$PCA = {}^2/_3 \times TCA = {}^2/_3 \times 4617\ ft^2 = 3078\ ft^2$

$Q_1 = 0.13\ gpm/ft^2 \times 3078\ ft^2 \times 1 = 400\ gal$

$Q_2 = 58\% \times Q_1 = 0.58 \times 400 = 232\ gal$

$Q_3 = 600$

now

$Q = Q_1 + Q_2 + Q_3$

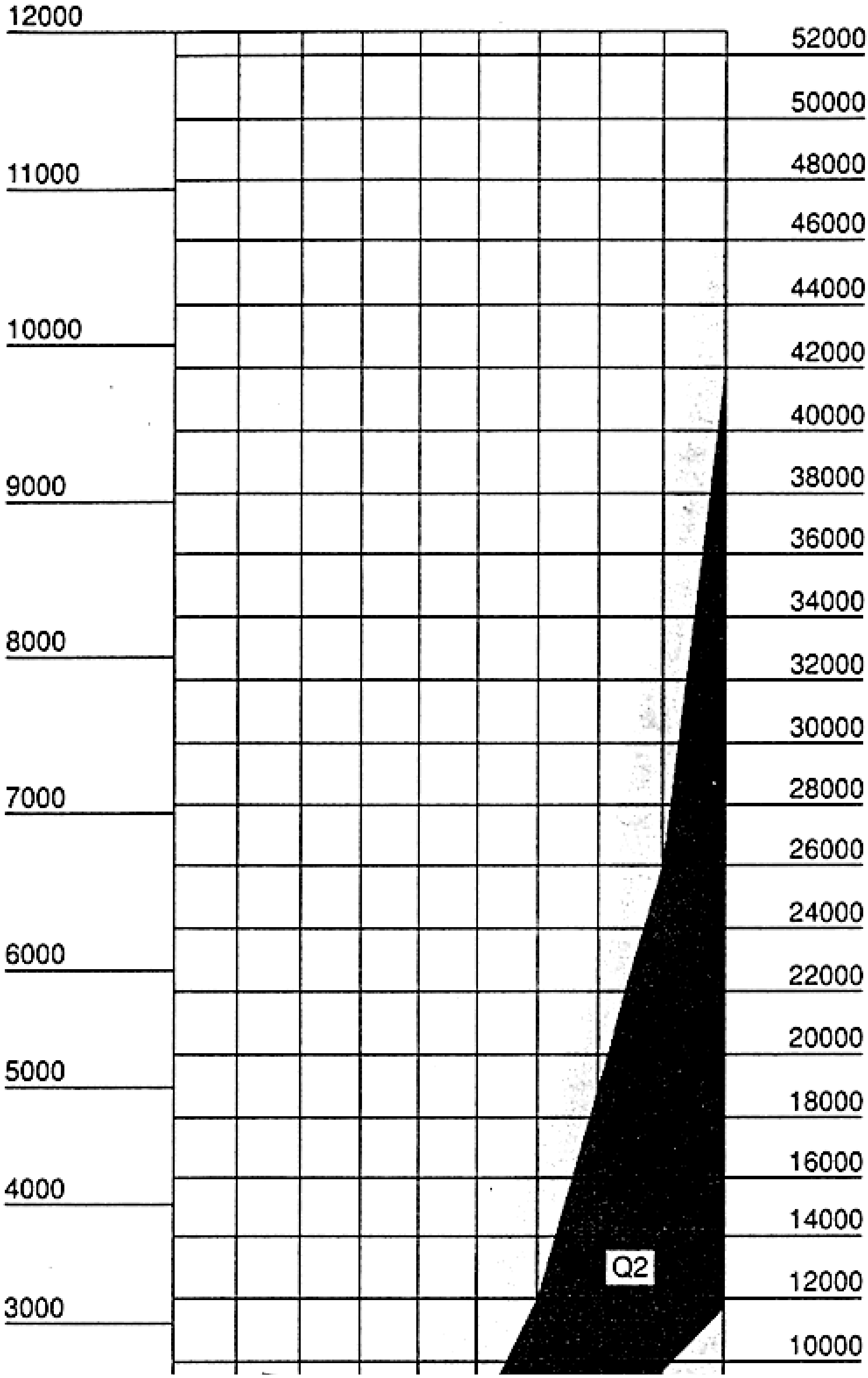
$= 400 + 232 + 600 = 1232\ gal$

or

$Q = 1200\ gal$ (rounded off)

This quantity is shown in the second column of Table 3-3.1(a).

The example is given to illustrate the logic and the factors used to arrive at the quantity of water for foam production required for an airport Category 4. For example, the aircraft length (L) and the aircraft external cabin width (W) are the midpoint length and width for Category 4.


12000
11000
10000
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40000
38000
36000
34000
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30000
28000
26000
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22000
20000
18000
16000
14000
12000
10000
Q2

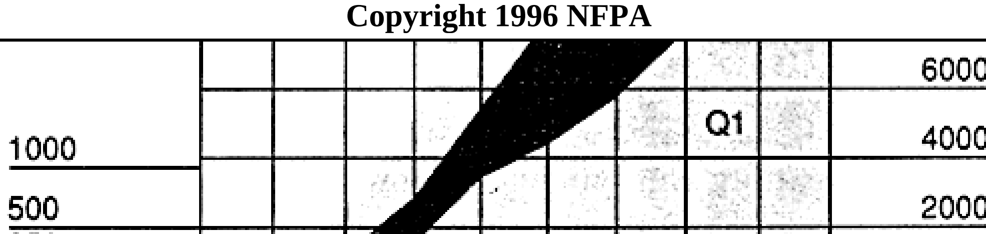
1000
500
6000
4000
2000
Q1

Figure A-2-3.1(b) Comparison by volume of Q_1, Q_2, Q_3, and Q.

Airport categories are used in the calculations to eliminate the need for calculating specific quantities of extinguishing agents for each type of aircraft.

Although only water is normally necessary for interior hand line attack, logistically and tactically it should be discharged as foam and is therefore added to the quantities of water necessary for foam production in Tables 3-3.1(a) and 3-3.1(b).

A-2-3.2 See Table A-2-3.2.

Table A-2-3.2 Representative Aircraft by Airport Categories

		Overall Fuselage Length		External Fuselage Width	
Airport Category	**Aircraft Type**	**feet**	**meters**	**feet**	**meters**
1	Beech Bonanza 35	26.33	8.01	3.05	1.07
	Cessna 206	26.90	8.20	4.00	1.22
	Mooney M-20	24.90	7.60	3.70	1.13
2	Cessna 414	36.30	11.06	4.70	1.43
	Piper Aerostar	34.80	10.60	3.90	1.19
	Piper Cheyenne 2	34.70	10.60	4.30	1.31
3	Beech 1900	57.90	17.65	4.60	1.40
	Beech Kingaire 200	43.80	13.35	5.80	1.77
	Lear 55	55.20	16.80	5.20	1.58
4	D.H. Dash 8	73.00	22.25	8.83	2.69
	Fokker F-27 2000	77.30	23.56	8.86	2.70
	Short 360	70.90	21.60	6.40	1.95
5	ATR 72	89.10	27.16	9.40	2.87
	D.H. Dash 7	80.70	24.60	8.50	2.59
	Gulfstream 3	83.10	25.30	7.40	2.71

6	BAE 146-200	93.67	28.55	11.68	3.56
	Airbus A-320 300	123.27	37.57	12.96	3.95
	Boeing 737-300	109.60	33.40	12.34	3.76
7	Boeing 727-200	156.16	46.68	12.34	3.76
	Boeing 757	155.30	47.34	13.00	3.96
	M.D. 88	147.90	45.10	10.96	3.34
8	Airbus A-300	175.90	53.61	18.50	5.64
	Boeing 767-300	180.30	54.96	16.50	5.03
	D.C. 10-40	182.23	55.54	19.75	6.02
	Lockheed L-1011	178.62	54.44	19.59	5.97
9	Airbus A-340 300	208.90	63.67	18.50	5.64
	Boeing 747-200	230.99	70.40	21.40	6.50
	Concorde	203.75	62.10	9.42	2.87
	M.D. 11	200.90	61.24	19.90	6.07
10	Antonov AN-225	275.70	84.10	20.90	6.40

A-3-1.1

Foams used for control and extinguishment of aircraft fires involving fuel spills are produced by incorporation of air into a solution of foam concentrate and water. Their characteristics, as indicated by expansion and drainage rate, are influenced by the amount of mechanical agitation to which the water, foam concentrate, and air are subjected. They extinguish fire by physically separating the fuel vapors from the heat and oxygen necessary for combustion, spreading over the surface of the fuel to effectively suppress vaporization and secure an extinguished area by protecting it from reignition. Foam, being essentially water, cools the surface of the fuel and any metal surfaces in the fuel. The solution drainage from some foams forms an aqueous film on most aviation fuels. It is advantageous for a foam blanket to reseal if disrupted, and essential that either the foam has good thermal and mechanical stability or that provision is made to renew the foam blanket from time to time during a lengthy rescue operation.

Foam liquid concentrates of different types or of different manufacturers should not be mixed unless it is first established that they are compatible. Protein and fluoroprotein foam concentrates, in particular, are generally not compatible with AFFF concentrates and should not be mixed, although foams generated separately from these concentrates are compatible and can be applied simultaneously to a fire. All foams used as primary agents are available for use at 3 percent and 6 percent concentrations, usually in either fresh or salt water, and some are for use at other concentrations such as 1 percent or 5 percent.

Foam can be produced in a number of ways. The method of foam production selected should be carefully weighed, considering the techniques best suited for the equipment concerned, the rates and patterns of discharge desired and the manpower needed to properly utilize the foam capabilities of the vehicles. The principal methods of foam production are given in NFPA 412, *Standard for Evaluating Aircraft Rescue and Fire Fighting Foam Equipment*.

The quality of water used in making foam can affect the foam performance. Locally available water might require adjustment of the proportioning device to achieve optimum foam quality. No corrosion inhibitors, freezing point depressants, or any other additives should be used in the water supply without prior consultation and approval of the foam concentrate manufacturer.

CAUTION: Converting aircraft crash fire fighting and rescue vehicles to use a type of foam concentrate other than that for which they were initially designed should not be accomplished without consultation with the equipment manufacturer and without a thorough flushing of the agent and the complete foam delivery system. Particular attention should be given to ensuring that the system component materials are suitable for the particular concentrate being substituted and that, where necessary, the proportioning equipment is recalibrated and reset.

CAUTION: Any salvageable aircraft that comes in contact with foam agents during fire fighting or fuel spill securing operations should be thoroughly flushed with fresh water as soon as practicable. Both the foam manufacturer and the airframe manufacturer should be contacted for any additional requirements that may be associated with specific foam agents or aircraft components.

A-3-1.2

The two test methods cited in 3-1.2 have wide application in North America but may not be recognized in other areas of the world. In particular, ICAO has developed guidance that references foam evaluation methods having significantly different test parameters such as test fuel, application rate, and extinguishment density. The intent of this standard is that primary foam agents meet minimum performance criteria. It is the intent that aqueous film forming foams achieve a level of performance consistent with the MIL-F-24385, when the lowest discharge rates/quantities in Tables 3-3.1(a) and 3-3.1(b) are used. The national (ICAO State) civil aviation authority having jurisdiction may adopt or reference standards recognized in that particular part of the world. It is incumbent on the national (ICAO State) authority to determine that alternate test methods are consistent with the minimum agent rates/quantities they have adopted. The national (ICAO State) civil aviation authority having jurisdiction should make this determination to prevent inconsistencies at the local or regional level.

A-3-1.2.1 Fresh water or sea water may be used for the fire test.

A-3-2(a) There are a number of chemical compounds offered on a proprietary basis that are referred to as dry chemical fire extinguishing agents. Historically, sodium bicarbonate-based compounds were initially so described, but in recent years, a number of other chemicals have been tested and potassium bicarbonate-based powders have proven most effective as a means of quickly extinguishing flammable liquid fires when applied with a proper technique and at an adequate rate. Potassium bicarbonate has good flooding characteristics and can penetrate to otherwise inaccessible areas. Dry chemicals, as currently used in aircraft rescue and fire fighting, can be used to extinguish three-dimensional liquid fuel or running fires where foam is present on the ground.

A-3-2(b) Halogenated extinguishing agents are hydrocarbons in which one or more hydrogen atoms have been replaced by atoms from the halogen series: fluorine, chlorine, bromine, or iodine. This substitution confers not only nonflammability but flame extinguishment properties to many of the resulting compounds. Halogenated agents are used both in portable fire extinguishers and in extinguishing systems. The three halogen elements commonly found in extinguishing agents are fluorine (F), chlorine (Cl) and bromine (Br).

The extinguishing mechanism of the halogenated agents is not clearly understood. However, there is undoubtedly a chemical reaction that interferes with the combustion processes. Halogenated agents act by chemically interrupting the continuing combination of the fuel radicals with oxygen in the flame chain reactions. This process is known as “chain breaking.”

The discharge of Halon 1211 may create hazards to personnel such as dizziness, impaired coordination, reduced visibility, and exposure to toxic decomposition products. In any proposed use of Halon 1211 where there is a possibility that people may be trapped in or enter into atmospheres made hazardous, suitable safeguards should be provided to ensure prompt evacuation of and to prevent entry into such atmospheres and also to provide means for prompt rescue of any trapped personnel. Breathing apparatus should be worn.

Halon 1211 is a liquefied gas discharged as an 85 percent liquid stream that forms a vapor cloud when in contact with the fire, which permits penetration of obstructed and inaccessible areas. Halon 1211 leaves no agent residue and is the preferred agent for aircraft tire fires, engine fires, interior aircraft fires, electrical component fires, and flightline vehicle/equipment engine fires. Halon agent is, however, included in the Montreal Protocol on Substances that Deplete the Ozone Layer, signed September 16, 1987. The protocol permits continued availability of halongenated fire extinguishing agents at reduced production levels until the year 1994. Halon use should be limited to extinguishment of unwanted fire and should not be used for routine training of personnel.

A-3-3.3

Fire fighting vehicles meeting the requirements of 3-3.2 carry a sufficient quantity of foam concentrate for one refill, therefore rapid water resupply is of prime importance. The reserve water supply may be maintained in tankers or structural equipment. Hydrants may be considered if they are adequately located. Mutual aid services can be considered for this purpose if they are capable of responding in the critical time required to maintain the fire attack.

A-3-4.1

It is important that the compatability of the foam and dry chemical agents be established if they are to be used together. Halon 1211 is compatible with all foams.

A-3-5.1

A variety of metals burn when heated to high temperatures by friction or exposure to external heat; others burn from contact with moisture or in reaction with other materials. Because accidental fires can occur during the transportation of these materials, it is important to understand the nature of the various fires and hazards involved. The most common combustible metals used in aircraft are magnesium and titanium.

The hazards involved in the control or complete extinguishment of combustible metal fires include extremely high temperatures, steam explosions, hydrogen explosions, toxic products of combustion, explosive reaction with some common extinguishing agents, breakdown of some extinguishing agents with the liberation of combustible gases or toxic products of combustion, and dangerous radiation in the case of certain nuclear materials. Some agents displace oxygen, especially in confined spaces. Therefore, extinguishing agents and methods for their specific application should be selected with care. Some combustible metal fires should not be approached without suitable self-contained breathing apparatus and protective clothing, even if the fire is small. Other combustible metal fires can be readily approached with minimum protection.

Numerous agents have been developed to extinguish combustible metal (Class D) fires, but a given agent does not necessarily control or extinguish all metal fires. Although some agents are valuable in working with several metals, other agents are useful in combating only one type of metal fire. Despite their use in industry, some of these agents provide only partial control and cannot be classified as actual extinguishing agents. Certain agents that are suitable for other classes of fires should be avoided in the case of combustible metal fires, because violent reactions can result (e.g., water on sodium; vaporizing liquids on magnesium fires).

Certain of the combustible metal extinguishing agents have been in use for years, and their success in handling metal fires has led to the terms “approved extinguishing powder” and “dry powder.” These designations have appeared in codes and other publications where it was not possible to employ the proprietary names of the powders. These terms have been accepted in describing extinguishing agents for metal fires and should not be confused with the name “dry chemical,” which normally applies to an agent suitable for use on flammable liquid (Class B) and live electrical equipment (Class C) fires.

A-4-1.1

It is desirable to have more than one vehicle available to facilitate attacking aircraft fires from more than one point or quarter, as an aid to expedite rescue, to reduce the potential seriousness of vehicle breakdown, and to minimize the “out of service” consequences when a vehicle is in need of routine maintenance or repairs. Having at least two fire fighting vehicles available is particularly important when dealing with transport-type aircraft due to the need to rapidly cover any burning fuel spill to protect the aircraft and its occupants from radiated heat during the evacuation and rescue period, and to maintain the secure area around the fuselage to permit the safe evacuation and rescue of the occupants.

A-4-1.2

The capacity of each vehicle with regard to fire fighting, rescue equipment, and staffing should be compatible with the desired performance characteristics established for vehicles in the various catagories specified in NFPA 414, *Standard for Aircraft Rescue and Fire Fighting Vehicles*. It is particularly important that the vehicle not be overloaded so as to reduce the required acceleration, top speed, or vehicle flotation below the acceptable minimums set forth in NFPA 414.

The off-pavement performance capability of each ARFF vehicle should be established by tests at each airport during the various weather and terrain conditions experienced at that airport to establish, prior to an actual emergency, the capabilities and limitations of the vehicle for off-pavement response to accident/incident locations. In addition, periodic tests should be conducted to ensure that the performance requirements of the vehicle are as originally designed, and that the skill levels of the driver/operators remain high.

Where climatic or geographic conditions exist that considerably reduce the effectiveness of conventional wheeled vehicles, it is often necessary to carry extinguishing agents in a specialized vehicle suitable for traveling the airport terrain, such as a tracked, amphibious, air-cushioned, or high-mobility wheeled vehicle. Where these difficult operational conditions exist, experts should be consulted to develop a vehicle specification that matches the vehicle's performance capabilities to the unique conditions present at the airport.

Overall vehicle dimensions should be within practical limits with regard to local highway practices, width of gates and height and weight limitations of tunnels and bridges, and other local considerations.

Simplicity of vehicle operation with emphasis on operation of the extinguishing agent discharge devices is extremely important due to the time restrictions imposed for successful aircraft rescue and fire fighting operations and the need to keep the fire fighting crew to the minimum required for safe and efficient operations. Successful control of the fire in the PCA is essential using the minimum amount of agent necessary to secure the objective. To control an aircraft fire it is necessary to apply extinguishing agents at a rate higher than the fire is capable of destroying the control effort. Hand hose lines are usually not adequate for fire involving larger types of aircraft due to their limited discharge rate and are used primarily for protection of rescue parties, maintaining control of the fire in the PCA area, and combating fires in aircraft interiors. For these reasons, turrets are needed to rapidly knock down the fire and secure the evacuation routes.

Improvements in vehicle and equipment design over recent years have increased the fire fighting efficiency of these units and have outdated older rescue and fire fighting vehicles. Before procuring any used vehicle for an airport rescue and fire fighting service, the possible savings in initial cost should be carefully weighed against the lower maintenance cost, the reduced manpower requirements, and the greater fire fighting efficiency that can be expected from new vehicles and equipment built in accordance with NFPA 414, *Standard for Aircraft Rescue and Fire Fighting Vehicles*. Secondhand vehicles might have been subjected to abusive service, components may have been overstressed, and repair parts might be impossible to obtain. Foam fire fighting equipment purchased for this service should be tested in accordance with NFPA 412, *Standard for Evaluating Aircraft Rescue and Fire Fighting Foam Equipment*.

Specialized vehicles such as elevated platform devices or aerial water towers might be needed at some airports to allow fire fighters to reach elevations above the normal range of airport ARFF vehicles. Provision of escape slides or other rapid evacuation systems on these vehicles might be invaluable in effecting a rapid rescue.

All essential vehicles should be provided with two-way radio communications with air traffic control (ATC) or the airport controlling facility, e.g., air-radio, flight service station, etc.

A-4-2

The following equipment should be carried on each ARFF vehicle:

(a) One ladder of overall length appropriate to the aircraft using the airport. This ladder is to be of lightweight alloy, aluminum or magnesium, 16-in. (40.6-cm) minimum width, mounted in quick-release brackets on the apparatus and readily accessible. This ladder is not intended for evacuation use.

(b) Rapid intervention vehicles and Class 1 major fire fighting vehicles should be equipped with a ladder capable of extending to a length of at least 16 ft (4.9 m).

Class 2, 3, and 4 major fire fighting vehicles should be equipped with a ladder capable of extending to a length of at least 20 ft (6.1 m).

(c) Two portable 6-volt electric, weatherproof, hand-held lanterns having a minimum 25,000 beam candle power rating with carrying straps.

(d) One 6-lb crash axe with a serrated cutting edge and designed to prevent full penetration.

(e) One adjustable hydrant wrench capable of accommodating up to a 1.75-in. (4.4-cm) pentagon nut and up to a 1.25-in. (3.2-cm) square nut.

(f) One set of double male and double female connectors to fit each tank fill connection size provided on the vehicle. The connector material should be specified.

(g) Appropriate coupling wrenches for each size of hose carried on the vehicle.

(h) Two approved fire extinguishers having a minimum 80B:C UL rating of either dry chemical or Halon 1211. The dry chemical extinguishers should be the external propellant cartridge type.

(i) One 36-in. (91.4-cm) crowbar.

(j) One “D” handle pike pole with a shaft of fiberglass or other nonconductive material of similar density.

(k) One rubber mallet suitable for removing long-handled pipe caps.

(l) One 36-unit first-aid kit.

(m) One general-purpose cutter with capacity to cut up to 0.38 in. diameter hardened steel (Bhn 300) bolts.

(n) Two Dzus fastener keys.

(o) One tool roll to include at least the following equipment:

(1) One aircraft cable cutter, 14-in. (35.6-cm), capacity to $^{1}/_{4}$ in. (0.6 cm).

(2) One lineman’s pliers, heavy duty, 8 in. (20.3 cm) long.

(3) One grappling hook and rope sling, 40 in. (101.6 cm) long.

(4) One hacksaw frame, adjustable 8 in. to 12 in. (20.3 cm to 30.5 cm).

(5) Three hacksaw blades, 10-in. (25.4-cm) steel.

(6) Six fuel line plugs: 3 hardwood, 3 neoprene.

(7) One rescue knife with “V” blade.

(8) One vise grip wrench, 10 in. (25.4 cm) long.

(9) One metal cutting saw, 20-in. (50.8-cm) blade.

(10) Two industrial grade slot-type screwdrivers [one 4- (10.2-cm) and one 6-in. (15.2-cm) blade].

(11) Two industrial grade Phillips screwdrivers [one 4- (10.2-cm) and one 6-in. (15.2-cm) blade].

(12) One hand axe with serrated face and insulated handle.

One hydraulic rescue kit should be carried on an in-service ARFF vehicle.

A-5-1.2

At those locations where the primary alerting authority (such as a control tower) is not operational during all the hours that the airport is open to aircraft traffic, a secondary alerting authority should be designated and trained. Appropriate communications and alarm control devices should be available at the secondary alerting authority’s operating location and be operational during all times that the primary alerting authority is not available.

At those locations where a city/town/county off-airport fire department furnishes the airport rescue and fire fighting personnel, and the alerting/dispatch of those personnel for airport emergencies is handled by an emergency direct-line telephone between the airport alerting authority and the off-airport alarm room, the airport fire station alarm(s) should ring upon activation of the direct emergency line. If possible, this type of “third party” dispatching of airport fire fighting and rescue services should be avoided.

Because the majority of the calls for aircraft ARFF services are initiated by or first received by air traffic controllers, the airport fire department alarm room and the control tower, the flight service station or other air traffic control point should be linked by two-way radio and direct-line telephone to enhance the response time of the fire and rescue crews.

The emergency direct-line telephone should not pass through any intermediate automated switchboard or operator that could subject the alert calls to delays.

The tone of the emergency telephone bell (or buzzer) should be distinctly different from all other communications signaling devices within hearing of personnel in the alarm room, on the apparatus floor, or in living quarters as applicable.

Protection against delays due to telephone bell/buzzer failure should be provided by use of redundant warning lights activated by the same input signal as the telephone ringer. The lights should be strategically located throughout the alarm room, the apparatus floor, and living space as dictated by the fire station design and the normal activities of the fire and rescue service personnel.

The fire station alarm should be linked to the emergency telephone so that a call on the emergency telephone circuit simultaneously actuates the audible alarm throughout the fire station.

Consideration should be given to having the alarm circuitry open the vehicle bay doors in the fire station upon sounding the alarm. However, some climatic conditions can make this impractical, or noise when doors are opened can interfere with hearing the dispatch.

The notification of all units designated to respond to an aircraft emergency on a large airport should be done through the use of a “conference” circuit that allows simultaneous notification. This “conference” circuit should include, as appropriate, the following units or offices:

(a) Control tower, flight service station, or other control point;

(b) Rescue and fire fighting;

(c) Airport police;

(d) Airport management;

(e) Airline station manager(s) as appropriate;

(f) Military units (joint-use airports); and

(g) Other authorities on or off the airport as required by the airport's emergency plan.

At airports with several air carriers, the notification of the appropriate station manager might be accomplished more effectively by the use of individual paging devices.

Fire stations where personnel are normally present for duty, but may be preoccupied with "housekeeping" or training duties, should be equipped with a public address system. This is particularly important in fire stations where the alarm room, training room, and living quarters are physically separated from the apparatus floor. Such a system should significantly enhance response time and fire fighter effectiveness by providing vital details of the emergency to each fire fighter during response, e.g., location of accident or incident site, type of aircraft, number of persons involved, aircraft fuel load, preferred vehicle routing, etc.

At airports with a main fire station and one or more substations, an interconnected public address system should be provided.

At airports employing dual function personnel or auxiliary fire fighters, an audible alarm should be installed in all areas where auxiliary fire fighting personnel are employed to notify them of any emergency recall for fire and rescue duties. It should be a distinctly different sound and loud enough to be clearly heard above the normal noise level.

At airports equipped with ground-to-air radio, the person authorized to receive in-flight emergency messages should be provided with a device for actuating these alarms.

Alarm actuating stations should be provided near hangars, shops, fueling stations, and aircraft parking areas.

Individual paging devices, although potentially more expensive, can be used. This method has the advantage of notifying those persons with assigned rescue fire fighting duties.

A reliable voice communications capability should be available between the airport rescue and fire fighting service and any off-airport organizations expected to participate in the airport-community mutual-aid plan.

Each emergency response vehicle on an airport should be equipped with two-way voice radio communication between the alerting authority, all other aircraft rescue and fire fighting vehicles, and the designated command post.

On airports with a control tower the communications channel between vehicles and the tower should be on the assigned standard ground control frequency, or as designated in the Airport Emergency Plan Letter of Agreement between airport management, the control tower and/or flight service station.

On airports without a control tower but having another means of ground-to-air communications, the rescue and fire fighting vehicles should be equipped to communicate on a frequency common with the control point.

Where practicable, the two-way radio capability on the airport fire and rescue service vehicle(s) should not be “tied into” Public Service frequencies (City-County or Airport Maintenance). This independent communications network will help ensure interruption-free communication in an emergency situation.

On-scene commanders (OSC) should have a communication capability while outside or remote from their vehicle communications systems. Portable radios can be used by the OSC for direct contact with the airport fire services and air traffic control services.

A reliable form of communication should be provided between the aircraft commander, the OSC, ARFF services, and the airport alerting authority to preclude unnecessary aircraft emergency evacuation or misunderstandings.

Direct communications can be established between the flight deck and the OSC or ARFF personnel by use of flight-deck-to-ground lines. Normally this communication capability results from the use of a ground service headset that is plugged into a wheel well or nose interphone jack.

The airport rescue and fire fighting service alarm room should be designed and operated in such a manner that an alarm can be received, evaluated, and acted upon with a minimum of activity or consultation.

For an alarm room to serve its intended function, provisions should be made to ensure that all personnel assigned to alarm room duties are trained in communication equipment operations, proper communication procedures, and local emergency plan implementation procedures.

A-6-1.4

A carefully organized training program should be developed to meet the qualification requirements of NFPA 1003, *Standard for Airport Fire Fighter Professional Qualifications*. The following guidelines are offered for structuring such a program.

The objectives of a training program for aircraft rescue and fire fighting personnel at airports should be to:

(a) Teach the safe application of recognized practices and procedures.

(b) Develop and maintain the confidence and competency of all personnel assigned ARFF duties;

(c) Instill the concept of professionalism;

(d) Serve as a source of accurate technical information whereby the lessons gained from aircraft accidents or incidents are properly analyzed and the information disseminated to others concerned with ARFF operations; and

(e) Enhance the esprit de corps of aircraft rescue and fire fighting personnel by creating an appreciative awareness of the hazards and dangers they may face in carrying out ARFF operations.

Control and Planning.

The complete training and educational program for aircraft rescue and fire fighting personnel should be under the direction of one officer of the airport fire department for planning, development, and supervision.

Resources for Training.

Training material resources for a training program oriented specifically to meet the needs of aircraft rescue and fire fighting personnel should take into consideration providing suitable amounts of extinguishing agents, such as foam concentrate, dry chemical, and Halon 1211; and fuel for training fires.

Phases of Training.

Training of aircraft rescue and fire fighting personnel should include seven phases. Training in all phases should be conducted for support personnel used as auxiliary fire fighters and for full-time aircraft rescue and fire fighting personnel. Because of the factor of time availability for schooling, the depth into which subjects are covered will vary, but the scope should not be reduced for auxiliary fire fighters.

Indoctrination.

Indoctrination training should include the following:

(a) The rules and regulations applicable to ARFF services;

(b) Knowledge of the basic duties and responsibilities and those of co-workers;

(c) Emergency response procedures;

(d) The command structures for administration and operations; and

(e) The importance of practicing occupational safety.

Operating ARFF Equipment.

All aircraft rescue and fire fighting personnel should be capable of effectively handling fire and rescue equipment under varied conditions of terrain and weather. The aim of training should be to ensure that every fire fighter is so well versed in handling all types of appliances and tools used in ARFF operations that under stressful conditions individual fire fighters can take effective action without the need for specific direction. Among the items that should be covered are:

(a) Complete knowledge of each tool and piece of equipment;

(b) The location of each piece of equipment and tool carried on each vehicle;

(c) The method of using each piece of equipment and tool, with emphasis on personal safety factors;

(d) Special handling precautions for the use of power tools;

(e) Knowledge of, and training in, the use of breathing apparatus and other protective equipment;

(f) The techniques employed in utilizing the available communication equipment;

(g) Knowledge of the apparatus, its built-in equipment, including the pump and its performance capabilities, the agents carried and their delivery systems;

(h) Actual operation of all vehicle controls and behind-the-wheel driver training under circumstances including negotiating obstacles and muddy or snow-covered soil conditions. This is done to provide a degree of assurance that the vehicle will not get bogged down or damaged during emergencies.

(i) Knowledge of departmental policies on positioning of apparatus for tactical service at accidents/incidents under the variety of possible conditions to be encountered; and

(j) Recordkeeping to document the efficiency and effectiveness of the various vehicles utilized by the airport fire department.

Fire Behavior and Fire Suppression.

Aircraft rescue and fire fighting personnel should possess a sound knowledge of fire behavior.

Instruction in this phase should include:

(a) The principles of combustion, with emphasis on the types of aircraft fuels;

(b) How fire propagates through the effects of heat conduction, convection, and radiation;

(c) The influence of fuel distribution on heat production;

(d) The principles of fire suppression by the various types of agents utilized in aircraft rescue and fire fighting operations;

(e) Live fire exercises that include but are not limited to exterior fuel fires, interior fires, engine fires, wheel fires, and fires involving on-board auxiliary power units; and

(f) The effects of heat exposure on individuals.

Training should be given covering the advantages and disadvantages of each fire extinguishing agent employed. Every opportunity should be taken to use the agents on realistic training fires. Each routine equipment test should be used as a training exercise to provide experience in the proper handling of the equipment, and to establish the proper technique of application of each agent available.

Rescue and Fire Fighting Procedure.

Care should be taken to ensure that aircraft rescue and fire fighting personnel fully understand that to achieve the objective of safeguarding the lives of those involved in an aircraft accident requires that fire in the practical critical area be controlled quickly and that this area be kept secure. Strict discipline should be maintained to ensure that fire suppression agents are not expended on fire outside the PCA until it is positively established that the immediate and long-term security of the PCA will not be jeopardized.

Personnel should be given thorough instructions in the following subject areas:

(a) The standard operating procedures (SOP) to be expected from the aircraft crew members under specified circumstances;

(b) The locations within aircraft where victim concentration may be anticipated under accident conditions of various types;

(c) Behavior patterns of individuals involved in major disasters;

(d) Means of preventing or minimizing panic;

(e) Means of gaining entry through normal aircraft openings;

(f) Locations most suitable for forcible entry into the aircraft;

(g) Requirements of setting up triage and treatment areas that should be part of the Airport/Community Emergency Plan (*see NFPA 424M, Manual for Airport/Community Emergency Planning*); and

(h) Methods of carrying injured persons (one-person and by teams).

Familiarization with Local Terrain.

A thorough knowledge of the terrain of the airport and its immediate vicinity is essential. The existence of any areas that may from time to time become impassable because of weather or other conditions (tides, growth of brush, etc.) should be known to all crew members. Training should include actual ARFF vehicle operations over primary and secondary travel routes on the airport and runway overrun areas. Familiarization with areas outside the airport boundary to which the on-airport ARFF equipment might be authorized to respond can be accomplished with other vehicles. Personnel should also receive training during periods of diminished visibility.

The instruction program should include:

(a) Locations of obstacles both temporary and permanent;

(b) Locations of exit points (gates and/or frangible sections) in the security fence;

(c) Location of rendezvous points for mutual-aid apparatus as planned in the airport/community emergency plan;

(d) Areas that might become impassable in inclement weather;

(e) Availability of helicopters, boats, swamp buggies, air-cushion vehicles or other off-road conveyances; and

(f) The operation of each ARFF vehicle and its capability to negotiate the existing terrain under the various conditions that may be anticipated.

Aircraft Familiarization Training.

Aircraft rescue and fire fighting personnel should be familiar with:

(a) Locations of phone jacks on different types of aircraft;

(b) The availability and method of operation of aircraft escape devices;

(c) The location of aircraft batteries, and means of disconnect;

(d) The amount and type of aircraft fuel carried and the fuel storage locations in each aircraft;

(e) The location and quantity of oxygen carried;

(f) Access to wheel wells, engine accessory compartments, and other areas of critical concern; and

(g) The fire behavior characteristics and locations in the aircraft of combustible metals (magnesium, titanium), plastics (cabin liners, seating), combustible insulation (for electrical wiring and sound deadening), hydraulic fluids, lubricating oil, rubber, and similar combustibles and flammable materials.

Emergency Medical Training.

Every member of the airport ARFF services should be given initial and recurrent training in emergency medical procedures.

A-6-2.1

Although NFPA 1971, *Standard on Protective Clothing for Structural Fire Fighting*; NFPA 1972, *Standard on Helmets for Structural Fire Fighting*; and NFPA 1973, *Standard on Gloves for Structural Fire Fighting*, do not apply to ARFF protective clothing, ARFF protective clothing should at least meet the minimum requirements of these standards. Guidance and proximity of protective clothing can be found in FAA Advisory Circular 150/5210-14, dated 12 March 1986.

Fire entry suits are not recommended for civil airport application. Rapid fire control afforded by present fire fighting equipment and short times for survival without fire control make the fire entry suit unnecessary and inappropriate.

A-6-2.2

Tests have shown that many toxic gases are produced when aircraft cabin interior finish materials are burned or charred. These gases include carbon monoxide, hydrogen chloride, chlorine, hydrogen cyanide and other cyanogen components, and carbonyl chloride (phosgene). A principal cause of difficulty lies in the fact that the supply of breathing air is greatly reduced by combustion of these cabin finish materials. It is, therefore, necessary that ARFF personnel who enter or operate in the vicinity of an aircraft during the fire sequence be equipped with self-contained breathing equipment. Helmets or hoods should be designed to accommodate the SCBA facepiece without interference; most existing proximity hoods do not have this provision.

A-7-1.1

Factors that influence response time include:

(a) The means of notification of the ARFF force;

(b) The completeness of the information in the activation message;

(c) The location of the fire station;

(d) The acceleration, top speed, on-road handling, and off-road mobility characteristics of the vehicles;

(e) The degree of preparatory training;

(f) The provision of emergency access roads; and

(g) Climatic conditions.

A-7-1.2

The geographical center of an airport might not be the best location for siting the airport fire station. Before selecting the actual location, time trials should be run to determine the optimum location that ensures the quickest response to all potential accident sites. Also, an evaluation should be placed on present and future usage of the airport movement areas to ensure proper selection of the fire station site. [*See Figures A-7-1.2(a) and (b)*.]

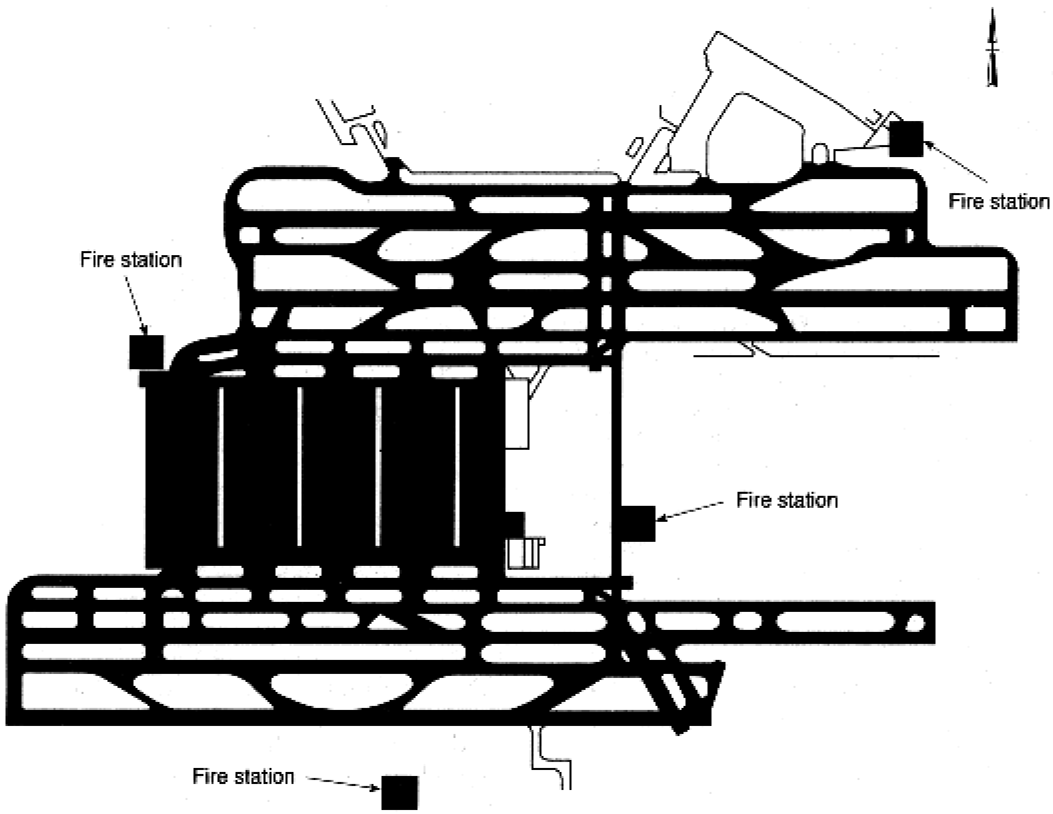

Figure A-7-1.2(a) Example of category 9 airport fire station locations.

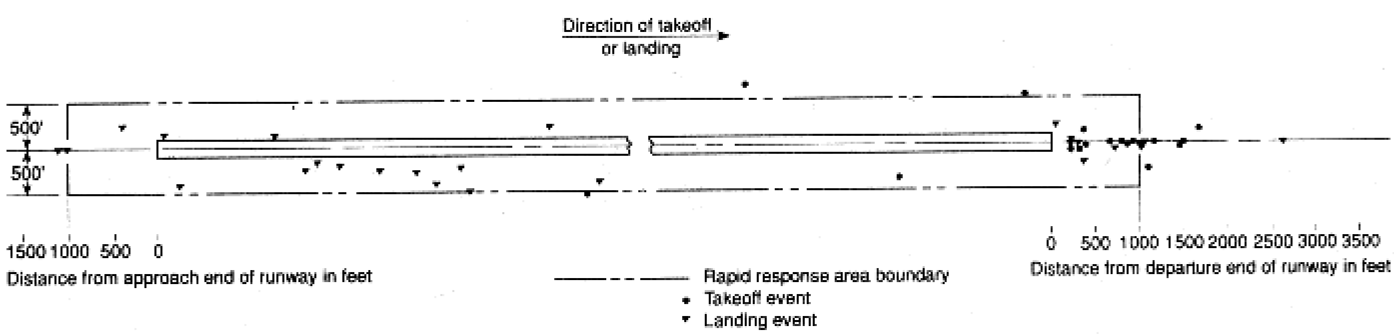

Figure A-7-1.2(b) Rapid response area (RRA) boundary.

Care should be taken to ensure that access to or from the airport fire station cannot and will not be blocked by taxiing or parked aircraft or vehicular traffic.

Airport fire stations located close to taxiways and runways or adjacent to flight patterns should have soundproof training rooms, living quarters, and an alarm room. The high noise level of turbine engines can cause damage to hearing; accordingly, at airports handling turbine-powered aircraft, fire fighters on duty outside of soundproofed areas should be provided with aural protection. Where high noise levels are encountered it might be necessary to supplement audible signals with visual signals, such as flashing lights, to alert fire fighters.

Where airport response plans call for response outside the airport fences, suitable exits should be provided around the perimeter of the airport for ARFF vehicles. Particular attention should be given to the provision of ready access to the RRA and CRFFAA. The critical rescue and fire fighting access area (CRFFAA) is the rectangular area surrounding any given runway. Its width extends 500 ft (150 m) outward from each side of the runway centerline, and its length is 3,300 ft (1000 m) beyond each runway end. This is the area where accidents historically have occurred. [*See Figure A-7-1.2(b).*]

A-7-1.3

Two or more airport fire stations should be strategically located on the airport where a centrally located fire station cannot meet the response criteria given in 7-1.3.

Appendix B Referenced Publications

B-1

The following documents or portions thereof are referenced within this standard for informational purposes only and thus are not considered part of the requirements of this document. The edition indicated for each reference is the current edition as of the date of the NFPA issuance of this document.

B-1.1 NFPA Publications.

National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.

NFPA 412, *Standard for Evaluating Aircraft Rescue and Fire Fighting Foam Equipment*, 1993 edition.

NFPA 414, *Standard for Aircraft Rescue and Fire Fighting Vehicles*, 1990 edition.

NFPA 424M, *Manual for Airport/Community Emergency Planning*, 1991 edition.

NFPA 1003, *Standard for Airport Fire Fighter Professional Qualifications*, 1987 edition.

NFPA 1971, *Standard on Protective Clothing for Structural Fire Fighting*, 1991 edition.

NFPA 1972, *Standard on Helmets for Structural Fire Fighting*, 1992 edition.

NFPA 1973, *Standard on Gloves for Structural Fire Fighting*, 1993 edition.

B-1.2 Other Publications.

International Fire Service Training Association Publication.

IFSTA 206, *Aircraft Fire Protection and Rescue Procedures*. Available from International Fire Service Training Association, Oklahoma State University, Stillwater, OK, 74078 or Canadian Association of Fire Chiefs, 1590-7 Liverpool Court, Ottawa, Canada K1B 4L2.

ICAO Publications.

Available from International Civil Aviation Organization, 1000 Sherbrooke St. W., Montreal, Quebec, Canada,* H3A 2R2.

International Standards and Recommended Practices - Aerodromes, Annex 14, 8th ed., March 1983.

Airport Services Manual, Part 1 - Rescue and Fire Fighting, 2nd ed., 1984, Doc 9137-AN/898, Part 1.

Airport Services Manual, Part 7 - Airport Emergency Planning, 1st ed., 1980, Doc 9137-AN/898, Part 7.

Airport Services Manual, Part 8 - Airport Operational Services, 1st ed., 1983, Doc 9137-AN/898, Part 8.

Heliport Manual, 2nd ed., 1985, Doc 9261-AN/903/2.

Training Manual, Aerodrome Fire Services Personnel, 1st ed., 1976, Doc 7912-AN/857, Part E-2.

Manual of Aircraft Accidents Investigation, 4th ed., 1970, Doc 6920-AN/855/4.

Aerodrome Manual, Part 6 - 4th ed., 1971, Doc. 7920-AN/865, Part 6.

*And other offices in Bangkok, Thailand; Cairo, Egypt; Dakar, Senegal; Lima, Peru; Mexico City, Mexico; Paris, France.

Air Line Pilots Association Publication.

ALPA - *Guide for Airport Standards*, 3rd ed., 1981. (Available from Air Line Pilots Association, Engineering and Air Safety Department, 535 Herndon Parkway, PO Box 1169, Herndon Virginia, 20070.)

Federal Aviation Administration Publications.

Available from the Department of Transportation, Distribution Requirements Section, M-494.1, Washington, DC 20590.

Advisory Circulars. This listing is limited to advisory circulars of substance concerning aircraft rescue and fire fighting. For complete listing of FAA advisory circulars write the FAA and request a copy of latest “Advisory Circular Checklist and Status of Federal Aviation Regulations.” This checklist is published periodically in the Federal Register.

150/5200-12A, Fire Department Responsibility in Protecting Evidence at the Scene of an Aircraft Accident (4-8-85). Guidance on the proper preservation of evidence at the scene of an aircraft accident.

150/5200-31, Airport Emergency Plan (1-27-89). (AAS-310). Provides guidance for the preparation of emergency plans at civil airports.

150/5210-2, Airport Emergency Facilities and Services (11-27-84). Provides information and advice so that airports may take specific voluntary preplanning actions to ensure at least minimum first-aid and medical readiness appropriate to the size of the airport in terms of permanent and transient personnel.

150/5210-5B, Painting, Marking, and Lighting of Vehicles Used on an Airport (7-11-86). Provides guidance, specifications, and standards, in the interest of airport personnel safety and operational efficiency, for painting, marking, and lighting of vehicles operating in the airport air operations area.

150/5210-G, Aircraft Fire and Rescue Facilities and Extinguishing Agents (1-28-85). Outlines scales of protection considered as the recommended minimum level.

150/5210-7B, Aircraft Fire and Rescue Communications (4-30-84). Provides guidance for planning and implementing an airport communications system for airport fire and rescue service.

150/5210-13A, Water Rescue Plans, Facilities, and Equipment (5-31-91). Provides guidance to assist airport operators in preparing for water rescue operations.

150/5210-14, Airport Fire and Rescue Personnel Protective Clothing (3-12-86). Developed to assist airport management in the development of local procurement specifications for an acceptable, cost-effective proximity suit for use in aircraft rescue and fire fighting operations.

150/5210-15, Airport Rescue and Fire Fighting Station Building Design (7-30-87). (AAS-100). Provides standards and guidance for planning, designing, and constructing an airport rescue and fire fighting station.

150/5210-16, Announcement of Availability: Standardized Basic Aircraft Rescue and Fire Fighting Curriculum (A Basic ARFF Training Course) (2-21-89). (AAS-314). Announces availability of subject course.

150/5220-4A, Water Supply Systems for Aircraft Fire and Rescue Protection (12-11-85). (AAS-120). Provides guidance for the water source selection and standards for a water distribution system designed to support aircraft rescue and fire fighting (ARFF) service operations on airports.

150/5220-10A, Guide Specification for Water/Foam Aircraft Rescue and Fire Fighting Vehicles (7-3-91). (AAS-120). Contains performance standards, specifications, and recommendations for the design, construction, and testing of a family of aircraft rescue and fire fighting (ARFF) vehicles.

150/5220-17A, Design Standards for an Aircraft Rescue and Fire Fighting Training Facility (1-31-92). (AAS-100). Contains standards, specifications, and recommendations for the design of an aircraft rescue and fire fighting training facility.

150/5230-4, Aircraft Fuel Storage, Handling, and Dispensing on Airports (8-27-82). (AAS-300). (Consolidated reprint includes changes 1 and 2). Provides information on aviation fuel deliveries to airport storage and the handling, cleaning, and dispensing of fuel into aircraft.

150/5370-2C, Operational Safety on Airports During Construction (5-31-84). Title is self-explanatory.

150/5390-2, Heliport Design (1-4-88). (AAS-100). Contains FAA guidelines, recommendations, and design standards for heliports and helistops developed after the date of this publication.

20-42C, Hand Fire Extinguishers for Use in Aircraft (3-7-84). (ACE-110). Provides methods acceptable to the administrator for showing compliance with the hand fire extinguisher provisions in FAR 25, 29, 91, 121, 125, 127, and 135 and provides updated general information.

FAR Part 139, Certification and Operations; Land Airports Serving Certain Air Carriers. (Available from the Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402.)

Department of Transportation Documents.

DOT/FAA/AS/80-2, Airport Crash/Fire/Rescue (CFR) Service Cost and Benefit Analysis (Vol

I Text, Vol. II Appendices). NTIS #PB 82-220773.

DOT/FAA/AS82-1, Airport Crash, Fire, and Rescue; Policy Alternatives Suitable for Further Analysis. NTIS #PB 82-220781.

DOT/FAA/AS/82-2, Airport Crash, Fire, and Rescue; Technical Research Program. NTIS #PB 82-220799.

DOT/FAA/AS/82-3, Airport Crash, Fire, and Rescue; Estimating the Effects of Leading Policy Alternatives. NTIS #PB 82-220807.

DOT/FAA/AS/82-4, A Cost-Benefit Analysis of Airport Crash, Fire, and Rescue Policy Alternatives: Summary and Recommendations. NTIS #PB 82-220815.

Copies of any or all of the reports can be purchased by submitting a request to the National Technical Information Service, 5288 Port Royal Road, Springfield, VA 22161, or by calling (703) 487-4650. Make check payable to “National Technical Information Service.”

NFPA 407

1996 Edition

Standard for Aircraft Fuel Servicing

1996 Edition

This edition of NFPA 407, *Standard for Aircraft Fuel Servicing*, was prepared by the Technical Committee on Aircraft Fuel Servicing and acted on by the National Fire Protection Association, Inc., at its Fall Meeting held November 13-15, 1995, in Chicago, IL. It was issued by the Standards Council on January 12, 1996, with an effective date of February 2, 1996, and supersedes all previous editions.

Changes other than editorial are indicated by a vertical rule in the margin of the pages on which they appear. These lines are included as an aid to the user in identifying changes from the previous edition.

This edition of NFPA 407 was approved as an American National Standard on February 2, 1996.

Origin and Development of NFPA 407

Active work by the National Fire Protection Association leading toward the development of this standard began in 1951. Since then, the technical committee responsible has made every effort to keep the text up-to-date, and subsequent editions have been published almost every year from 1955 to 1975. The 21st edition was issued in 1980, and the technical committee completed a partial revision in 1984.

The 1990 edition was a complete rewrite that reorganized the design and operational requirements into separate chapters. The requirements for grounding were deleted, and the requirements for bonding were clarified.

This edition is a partial revision. Requirements for self-service fueling and rapid refueling of helicopters were added.

Technical Committee on Aircraft Fuel Servicing

Bruce R. Pashley, *Chair*
Ogden Allied Aviation Services, NY

Stanley J. Wolek, *Vice Chair*
The Port Authority of New York & New Jersey, NJ
Rep. Airport Operators Council International Inc.

Howard M. Gammon, *Secretary*
Gammon Technical Products Inc., NJ

Terry Bosserman, Bosserman Aviation Equipment, Inc., OH

Siben Chakraborti, Transport Canada, Ontario, Canada

Melvin W. Girl, Phillips 66, OK

Thomas W. Hedberg, TKDA Inc., MN

Peter J. Hiavac, Garsite Inc., NY

Michael Klutz, Robert & Co., GA

Joseph T. Leonard, U.S. Naval Research Lab, DC

Mark R. McClaran, Carter Ground Fueling Co., CA

Francis P. O'Neill, United Airlines Inc. (SFOFU), CA

John J. O'Sullivan, British Airways, England

John A. Park, Burns & McDonnell Engr Co., Inc., MO

Claude Taucher, American Airlines, OK

Committee Scope: This Committee shall have primary responsibility for documents on fire-safe procedures, equipment, and installations for aircraft fuel servicing.

NFPA 407

Standard for Aircraft Fuel Servicing

1996 Edition

NOTICE: An asterisk (*) following the number or letter designating a paragraph indicates explanatory material on that paragraph in Appendix A.
Information on referenced publications can be found in Chapter 4 and Appendix B.

Chapter 1 Administration

1-1 Scope.

This standard applies to the fuel servicing of all types of aircraft using liquid petroleum fuel. It does not apply to the following:

(a) In-flight fueling;

(b) Fuel servicing of flying boats or amphibious aircraft on water; or

(c) Draining or filling of aircraft fuel tanks incidental to aircraft fuel system maintenance operations or manufacturing.

1-2* Purpose.

1-2.1

The purpose of this standard is to establish reasonable minimum fire safety requirements for procedures, equipment, and installations for the protection of persons, aircraft, and other property during ground fuel servicing of aircraft using liquid petroleum fuels. These requirements are based upon sound engineering principles, test data, and field experience.

1-2.2

The fire hazard properties of aviation fuels vary; however, for the purpose of this standard, the same fire safety precautions are specified for all types.

1-3 Definitions.

Aircraft. A vehicle designed for flight that is powered by liquid petroleum fuel.

Aircraft Fueling Vehicle. A fuel servicing hydrant vehicle or an aircraft fuel servicing tank vehicle.

Aircraft Fuel Servicing. The transfer of fuel into or from an aircraft.

Aircraft Fuel Servicing Hydrant Vehicle (Hydrant Vehicle). A vehicle equipped with facilities to transfer fuel between a fuel hydrant and an aircraft.

Aircraft Fuel Servicing Ramp or Apron. An area or position at an airport used for the fuel servicing of aircraft.

Aircraft Fuel Servicing Tank Vehicle (Fueler). A vehicle having a cargo tank (tank truck, tank full trailer, tank semitrailer) designed for or used in the transportation and transfer of fuel into or from an aircraft.

Airport Fueling System. An arrangement of aviation fuel storage tanks, pumps, piping, and associated equipment, such as filters, water separators, hydrants and station, or aircraft fuel servicing vehicles, installed at an airport and designed to service aircraft at fixed positions.

Approved.* Acceptable to the authority having jurisdiction.

Authority Having Jurisdiction.* The organization, office, or individual responsible for approving equipment, an installation, or a procedure.

Aviation Fuel.* Any petroleum fuel for use in aircraft engines.

Baffle. A non-liquidtight transverse partition in a cargo tank.

Bulkhead. A liquidtight transverse closure between compartments of a cargo tank.

Burst Pressure. See Pressure.

Cargo Tank. A container used for carrying aircraft fuels and mounted permanently or otherwise secured on a tank vehicle. The term “cargo tank” does not apply to any container used solely for the purpose of supplying fuel for the propulsion of the vehicle on which it is mounted.

Cathodic Protection. A method of controlling or impressing an electrical current to prevent corrosion of metal components of airport fueling systems that are in contact with the ground.

Compartment. A liquidtight division in a cargo tank.

Deadman Control. A device that needs a positive continuing action by a person to allow the flow of fuel.

Electric Hand Lamp. A portable lamp other than a flashlight.

Emergency Fuel Shutoff. A function performed to stop the flow of fuel in an emergency.

Fueler. See Aircraft Fuel Servicing Tank Vehicle (Fueler).

Fuel Servicing Station. A unit that includes all necessary equipment to enable the transfer of fuel into or from an aircraft or fueler. This unit can be installed in a cabinet above or below the ground.

Head. A liquidtight transverse closure at the end of a cargo tank.

Hydrant Valve. An outlet of an airport fueling system that includes a deadman-controlled valve and adapter assembly to which a coupler on a hose or other flexible conduit on an aircraft fuel servicing vehicle can be connected.

Hydrant Vehicle. See Aircraft Fuel Servicing Hydrant Vehicle (Hydrant Vehicle).

Labeled. Equipment or materials to which has been attached a label, symbol, or other identifying mark of an organization that is acceptable to the authority having jurisdiction and concerned with product evaluation that maintains periodic inspection of production of labeled equipment or materials and by whose labeling the manufacturer indicates compliance with appropriate standards or performance in a specified manner.

Listed.* Equipment or materials included in a list published by an organization acceptable to the authority having jurisdiction and concerned with product evaluation that maintains periodic inspection of production of listed equipment or materials and whose listing states either that the equipment or material meets appropriate standards or has been tested and found suitable for use in a specified manner.

Misfueling. The accidental fueling of an aircraft or refueling vehicle tank with an improper grade of product.

Overshoot. The quantity of fuel passing through the valve after the deadman control is released.

Pressure.

Burst Pressure. The pressure at which a component ruptures.

Test Pressure. The pressure to which a system or a component of a system is subjected to verify the integrity of the system or component.

Working Pressure. The maximum allowable pressure, including momentary surge pressure, to which a system, hose, or other component can be safely subjected while in service.

Pressure Fuel Servicing. A system used to fuel an aircraft by close coupling under pressure.

Self-service Fueling. The dispensing of aviation fuels into aircraft fuel tanks by persons other than the facility owner/operator.

Shall. Indicates a mandatory requirement.

Should. Indicates a recommendation or that which is advised but not required.

Tank Full Trailer. A vehicle that is not self-propelled and that has a cargo tank for the transportation of aviation fuel mounted thereon or built as an integral part thereof. It is so constructed that its weight and load rest on its own wheels.

Tank Semitrailer. A vehicle that is not self-propelled and that has a cargo tank for the transportation of aviation fuel mounted thereon or built as an integral part thereof. It is so constructed that, when drawn by a tractor by means of a fifth wheel connection, some of its load and weight rests upon the towing vehicle.

Tank Truck. A self-propelled vehicle having a cargo tank for the transportation of aviation fuel.

Tank Vehicle. Any tank truck, tank full trailer, or tractor and tank semitrailer combination.

Test Pressure. See Pressure.

Working Pressure. See Pressure.

1-4 Units.

Where the value for a measurement as specified in this standard is followed by an equivalent value in other units, the first value shall be regarded as the requirement. The equivalent value could be approximate.

Chapter 2 Design

2-1 General.

2-1.1 Fueling Hose Apparatus.

Nozzle receptacles and hose storage apparatus shall be arranged to avoid kinks and short loops in hoses.

2-1.2 Electrostatic Hazards and Bonding.

2-1.2.1 A provision for bonding shall be incorporated in the design of fuel servicing vehicles and systems to prevent differences in electrostatic potential in accordance with Section 3-4.

2-1.2.2 Bonding cables shall be constructed of conductive, durable, and flexible material.

2-1.2.3 Bonding connections shall be electrically and mechanically firm. Jacks, plugs, clamps, and connecting points shall be clean, unpainted metal to provide a positive electrical connection.

2-1.2.4 API BULL 1529, *Aviation Fueling Hose*, Type C hose, or BS 3158, *Rubber Hoses and Hose Assemblies for Aircraft Ground Fueling and Defueling*, Type C (conductive) hose, shall be used to prevent electrostatic discharges but shall not be used to accomplish required bonding. API BULL 1529, Type A, BS 3158, Type A, and hose having a static wire in the hose wall shall not be used.

2-1.2.5* The design shall incorporate the provision of a 30-second relaxation period between the filter separator and the discharge outlet.

Exception: This requirement shall not apply to systems designed for fuels with static dissipater additives.

2-1.3 No Smoking Signs.

Entrances to fueling areas shall be posted with "no smoking" signs.

2-1.4 Radar Equipment.

2-1.4.1 Aircraft Radar Equipment.

2-1.4.1.1 Surveillance radar equipment in aircraft shall not be operated within 300 ft (90 m) of any fueling, servicing, or other operation in which flammable liquids, vapors, or mist might be present.

2-1.4.1.2 Weather-mapping radar equipment in aircraft shall not be operated while the aircraft in which it is mounted is undergoing fuel servicing.

2-1.4.2* Ground Radar Equipment.

2-1.4.2.1 Antennas of airport flight traffic surveillance radar equipment shall be located so that the beam will not be directed toward any fuel storage or loading racks within 300 ft (90 m). Aircraft fuel servicing shall not be conducted within this 300-ft (90-m) distance.

2-1.4.2.2 Antennas of airport ground traffic surveillance radar equipment shall be located so that the beam will not be directed toward any fuel storage or loading racks within 100 ft (30 m). Aircraft fuel servicing or any other operations involving flammable liquids or vapors shall not be conducted within 100 ft (30 m) of such antennas.

2-1.5 Emergency Fire Equipment Accessibility.

Accessibility to aircraft by emergency fire equipment shall be considered in establishing aircraft fuel servicing positions.

2-1.6 Portable Fire Extinguishers.

2-1.6.1* Portable extinguishers shall be provided in accordance with 2-3.8 and Section 3-13.

2-1.6.2 Extinguishers shall conform to the requirements of NFPA 10, *Standard for Portable Fire Extinguishers*.

2-1.7* Deadman Controls.

2-1.7.1 The valve that controls the flow of fuel to an aircraft shall have a deadman control. The deadman control device shall be arranged to accommodate the operational requirements of Section 3-15. The fuel flow control valve shall be one of the following:

(a) The hydrant pit valve;

(b) At the tank outlet on a tank vehicle;

(c) A separate valve on the tank vehicle; or

(d) On the hose nozzle for overwing servicing.

2-1.7.2 Deadman controls shall be designed to preclude defeating their intended purpose.

2-1.8 Pressure Fuel Servicing System Controls.

The system shall be designed to minimize surge pressure. The overshoot shall not exceed 5 percent of actual flow rate from the time the deadman is released until the flow stops completely. The control valve shall be located and designed so that it will not be rendered inoperative by a surface accident, power failure, or spill. It shall be fail-safe by closing completely in the event of control power loss.

2-2* Aircraft Fueling Hose Requirements.

2-2.1 Performance Requirements.

Hose shall comply with the requirements of API BULL 1529, *Aviation Fueling Hose*, or BS 3158, *Rubber Hoses and Hose Assemblies for Aircraft Ground Fueling and Defueling*. Couplings shall comply with the requirements of API BULL 1529.

2-2.2 Additional Requirements.

2-2.2.1 Each coupled length of hose shall be tested at the same minimum proof pressure rating for that grade of hose as defined in API BULL 1529, *Aviation Fueling Hose*.

2-2.2.2 A test certificate shall be provided for each coupled length of hose and shall state the following:

(a) Manufacturer's name (hose);

(b) Manufacturer's name (couplings);

(c) Hose type;

(d) Hose grade;

(e) Size and length of hose;

(f) Serial number or reference number of hose;

(g) Quarter and year of manufacture of hose;

(h) Model number of couplings;

(i) Sizes of coupling ferrules;

(j) Hydrostatic test pressures;

(k) Coupled length serial number;

(l) Identification of individual responsible for coupling the hose;

(m) Name and address of company responsible for coupling the hose;

(n) Date of certification.

2-2.2.3 The coupling tests as specified in API BULL 1529, *Aviation Fueling Hose*, shall be performed for each hose grade, type, and manufacturer.

2-2.2.4 Each coupling of a coupled length of hose shall be permanently marked with a serial number corresponding to its hydrostatic test certificate.

2-2.2.5 The hose at the end of each coupling ferrule shall be permanently marked prior to hydrostatic testing to serve as a reference to determine whether a coupling has slipped during testing or while in service.

2-2.3 Hydrostatic Testing.

Hydrostatic testing shall be in accordance with ASTM D 380, *Standard Test Methods for Rubber Hose*.

2-2.3.1 Following a hydrostatic test, all of the water shall be drained and the hose shall be dried internally. The open ends, including the threads of the couplings, shall be suitably covered to protect the threads and to prevent contamination.

2-2.3.2 A hose that is recoupled for any reason shall be hydrostatically tested and recertified to the same criteria as a newly coupled hose.

2-3 Aircraft Fuel Servicing Vehicles.

Aircraft fuel servicing tank vehicles that are used on public highways also shall comply with NFPA 385, *Standard for Tank Vehicles for Flammable and Combustible Liquids*.

2-3.1 Materials.

2-3.1.1 In addition to any specific requirements in this chapter, only materials safe for use in the service intended and compatible with fuel applications shall be used in the construction of aircraft fuel servicing vehicles.

2-3.1.2 Magnesium shall not be used in the construction of any portion of an aircraft fuel servicing vehicle.

2-3.2 Vehicle Cargo Tanks.

Every cargo tank shall be supported by and attached to, or shall be a part of, the tank vehicle upon which it is carried in accordance with NFPA 385, *Standard for Tank Vehicles for Flammable and Combustible Liquids*.

2-3.3 Static Protection.

2-3.3.1 All metallic components and vehicle chassis shall be electrically bonded to prevent a difference in their electrostatic potential.

2-3.3.2 A provision shall be made for the bonding of the tank to the fill pipe or the loading rack as specified in 3-20.2.1. Electrical continuity between the loading rack and fill pipe shall be accomplished as specified in Section 3-4.

2-3.3.3 Cables shall be provided on the vehicle to allow the bonding operations specified in Section 3-4.

2-3.3.4 A cable with a clip or plug shall be attached to each overwing nozzle to facilitate compliance with 3-4.2.

2-3.4 Containers and Systems for Flammable Liquids Other than Cargo Tanks.

2-3.4.1 Vehicle fuel tanks and containers for other flammable liquids shall be made of metal and shall be designed, constructed, and located in a manner that precludes hazardous arrangements. Tanks shall be substantially protected by their location, and fill pipes shall not project beyond the vehicle profile. Tanks and containers shall vent away from sources of ignition during filling. Any arrangement not protected by location shall be listed for such use. The fuel tank arrangement shall allow for drainage without the tank's removal from its mountings.

2-3.4.2 Gravity feed systems shall not be used.

2-3.4.3 All portions of the flammable liquid feed system shall be constructed and located to minimize the fire hazard. The lines shall be made of materials not adversely affected by the fluid or by other materials likely to be encountered; shall be of adequate strength for the purpose; and shall be secured to avoid chafing or undue vibration.

2-3.4.4 The engine air intake shall retain the manufacturer's configuration to prevent the emission of flame in case of backfiring.

2-3.4.5 Where provided, the sediment bowl in the fuel supply line shall be of steel or material of equivalent fire resistance.

2-3.5 Engine Exhaust System.

2-3.5.1 The engine exhaust system shall be designed, located, and installed to minimize the hazard of fire in the event of the following:

(a) Leakage of fuel from the vehicle fuel tank or fuel system;

(b) Leakage from the fuel dispensing system of the vehicle;

(c) Spillage or overflow of fuel from the vehicle fuel tank or the cargo tank; or

(d) Spillage of fuel during the servicing of an aircraft.

2-3.5.2 Exhaust system components shall be secured and located clear of components carrying flammable liquids and separated from any combustible materials used in the construction of the vehicle.

2-3.5.3 Suitable shielding shall be provided to drain possible fuel spillage or leakage away from exhaust system components safely.

2-3.5.4 Exhaust gases shall not be discharged where they could ignite fuel vapors that might be released during normal operations or by accidental spillage or by leakage of fuel.

2-3.5.5 A muffler (or silencer) cutout shall not be provided.

2-3.6 Vehicle Lighting and Electrical Equipment.

2-3.6.1 Wiring shall be of adequate size to provide the required current-carrying capacity and mechanical strength. It shall be installed to provide protection from physical damage and from contact with spilled fuel either by its location or by enclosing it in metal conduit or other oil-resistant protective covering. All circuits shall have overcurrent protection. Junction boxes shall be weatherproofed.

2-3.6.2 Spark plugs and other exposed terminal connections shall be insulated to prevent sparking in the event of contact with conductive materials.

2-3.6.3* Motors, alternators, generators, and associated control equipment located outside of the engine compartment or vehicle cab shall be of a type listed for use in accordance with NFPA 70, *National Electrical Code*®, Class I, Division 1, Group D locations.

2-3.6.4 Electrical equipment and wiring located within a closed compartment shall be of a type listed for use in accordance with NFPA 70, *National Electrical Code*, Class I, Division 1, Group D locations.

2-3.6.5 Lamps and switching devices, other than those covered in 2-3.6.3 and 2-3.6.4, shall be of the enclosed, gasketed, weatherproof type. Other electrical components shall be of a type listed for use in accordance with NFPA 70, *National Electrical Code*, Class I, Division 2, Group D locations.

2-3.6.6 Electrical service wiring between a tractor and trailer shall be designed for heavy duty service. The connector shall be of the positive-engaging type. The trailer receptacle shall be mounted securely.

2-3.7 Cabinets.

All cabinets housing vehicle auxiliary equipment shall have expanded metal flooring, perforated metal grating-type flooring, or open floor to facilitate air circulation within the enclosed space and to prevent the accumulation of fuel.

2-3.8 Fire Extinguishers for Aircraft Fuel Servicing Vehicles.

2-3.8.1 Each aircraft fuel servicing tank vehicle shall have two listed fire extinguishers, each having a rating of at least 20B with one extinguisher mounted on each side of the vehicle.

2-3.8.2 There shall be one listed extinguisher having a rating of at least 20B installed on each hydrant fuel servicing vehicle.

2-3.8.3 Extinguishers shall be readily accessible from the ground. The area of the paneling or tank adjacent to or immediately behind the extinguisher(s) on fueling vehicles shall be painted with a contrasting color.

2-3.8.4 Extinguishers shall be kept clear of elements such as ice and snow. Extinguishers located in enclosed compartments shall be readily accessible, and their location shall be marked clearly in letters at least 2 in. (50 mm) high.

2-3.9 Full Trailers and Semitrailers.

2-3.9.1 Trailer connections shall be designed to secure the trailer firmly and to prevent the towed vehicle from swerving from side to side at the speeds anticipated so that the trailer essentially remains in the path of the towing vehicle.

2-3.9.2 Full trailers and semitrailers shall be equipped with brakes on all wheels.

2-3.10 Smoking Restrictions.

2-3.10.1 A “no smoking” sign shall be posted prominently in the cab of every aircraft fuel servicing vehicle.

2-3.10.2 Smoking equipment such as cigarette lighters and ash trays shall not be provided. If a vehicle includes such equipment when initially procured, it shall be removed or rendered inoperable.

2-3.11 Cargo Tanks.

2-3.11.1 Cargo tanks shall be constructed in accordance with NFPA 385, *Standard for Tank Vehicles for Flammable and Combustible Liquids*.

2-3.11.2 Aluminum alloys for high strength welded construction shall be joined by an inert gas arc welding process using filler metals R-GR40A, E-GR40A (5154 alloy), R-GM50A, and E-GM50A (5356 alloy) in accordance with AWS A5.10, *Specification for Bare Aluminum and Aluminum Alloy Welding Electrodes and Rods*.

2-3.11.3 Tank outlets shall be of substantial construction and shall be attached securely to the tank.

2-3.11.4 Every cargo tank or compartment over 90 in. (2286 mm) long shall be provided with baffles, the total number of which shall be such that the distance between any two adjacent baffles, or between any tank head or bulkhead and the baffle closest to it, shall in no case exceed 60 in. (1524 mm). The cross-sectional area of each baffle shall be not less than 80 percent of the cross-sectional area of the tank, and the thickness of a baffle shall be not less than that required for the heads and bulkheads of the cargo tank in which it is installed.

2-3.11.5 Venting shall be in accordance with NFPA 385, *Standard for Tank Vehicles for Flammable and Combustible Liquids*.

2-3.11.6 Cargo drawoff valves or faucets projecting beyond the frame of a tank vehicle shall be protected against damage.

2-3.12 Fill Openings and Top Flashings.

2-3.12.1 Dome covers shall be provided with a forward-mounted hinge and self-latching catches and shall be fitted with watertight fuel-resistant seals or gaskets (designed to prevent spillage or leakage from overturn and to prevent water entry). Dome covers shall automatically close and latch with the forward motion of the vehicle.

2-3.12.2 Drains from top flashing shall divert spilled fuel from possible sources of ignition, including the engine, the engine exhaust system, the electrical equipment, or an auxiliary equipment enclosure.

2-3.12.3 The tank fill openings shall be protected against overturn damage by a rigid member(s) fixed to the tank and extending a minimum of 1 in. (25 mm) above any dome cover, handle, vent opening, or projection of the unit. Overturn protection shall be braced adequately to prevent collapse. The overturn protection shall be designed to channel rain water, snow, or fuel to the exterior of the cargo tank.

2-3.13 Piping, Joints, Flanged Connections, and Couplings.

2-3.13.1 Product piping shall be metal and rated for the system working pressure or at least 125 psi (860 kPa), whichever is greater.

2-3.13.2 Except as provided in 2-3.13.3, all joints shall be welded. Elbows and fittings shall be kept to a minimum and, where used, shall be of the preformed welding type.

2-3.13.3 Flanged connections or approved couplings shall be provided to avoid the need for cutting and welding where components are serviced or replaced. Gaskets in flanged connections shall be of a material and design that resist fire exposure for a time comparable to the flange and bolts.

2-3.13.4 Piping shall be supported adequately.

2-3.14 Outlet Valves and Emergency Shutoff Controls.

2-3.14.1 The outlets of each cargo tank or compartment, including water drawoffs, shall be equipped with shutoff valves located inside the shell, or in the sump where it is an integral part of the shell. The cargo tank outlet shall be designed so that the valve needs to be kept closed except during loading and unloading operations. The water drawoff connection shall be of a type that cannot be blocked open.

2-3.14.2 The operating mechanism for each tank outlet valve shall be adjacent to the fuel delivery system operating controls and shall be arranged so that the outlet valve(s) can be closed simultaneously and instantly in the event of a fire or other emergency. There shall be at least two emergency shutoff controls, one mounted on each side of the vehicle. These controls shall be quick-acting to close the tank outlet valve in case of emergency. They also shall be remote from the fill openings and discharge outlets and shall be operable from a ground-level standing position. In addition, all vehicles equipped with a top deck platform shall have an emergency shutoff control operable from the deck.

2-3.14.3 Emergency fuel shutoff controls shall be placarded “EMERGENCY FUEL SHUTOFF” in letters at least 2 in. (50 mm) high and shall be of a color that contrasts with the placard background for visibility. The method of operation shall be indicated by an arrow or by the word “PUSH” or “PULL,” as appropriate. The words “EMERGENCY FUEL SHUTOFF” shall not be used to identify any control or device on the vehicle other than the emergency fuel shutoff controls.

2-3.14.4 Each outlet valve shall be provided with a fusible device that causes the valve to close automatically in case of fire.

2-3.14.5 A shear section shall be provided between shutoff valve seats and discharge outlets that breaks under strain unless the discharge piping is arranged to afford the same protection and leave the shutoff valve seat intact.

2-3.14.6 Openings in cargo tank compartments that are connected to pipe or tubing shall be fitted with a spring-loaded check valve, a self-closing valve, or similar device to prevent the accidental discharge of fuel in case of equipment malfunction or line breakage. Unless such valves are located inside the tank, they shall be equipped with a shear section as described in 2-3.14.5.

2-3.15 Fuel Dispensing System.

2-3.15.1 The valve that controls the flow of fuel from an aircraft fuel servicing vehicle to an aircraft shall have a deadman control(s) in accordance with the requirements of 2-1.7.

2-3.15.2 The deadman flow control in the nozzle shall be permitted for overwing fueling. Notches or latches in the nozzle handle that could allow the valve to be locked open shall be prohibited. Each overwing servicing nozzle shall have a cable with a plug or clip for bonding to the aircraft. (*See 3-4.2.*)

2-3.15.3 Nozzles for underwing fueling shall be designed to be attached securely to the aircraft adapter before the nozzle can be opened. It shall not be possible to disengage the nozzle from the aircraft adapter until the nozzle is fully closed.

2-3.15.4 Fuel servicing pump mechanisms shall be designed and arranged so that failure or seizure does not cause rupture of the pump housing, a tank, or of any component containing fuel. Fuel pressure shall be controlled within the stress limits of the hose and plumbing by means of either an in-line pressure controller, a system pressure relief valve, or other suitable means. The working pressure of any system component shall equal or exceed any pressure to which it could be subjected.

2-3.15.5 On tank full trailer or tank semitrailer vehicles, the use of a pump in the tractor unit with flexible connections to the trailer shall be prohibited unless the following conditions exist:

(a) Flexible connections are arranged above the liquid level of the tank in order to prevent gravity or siphon discharge in case of a break in the connection or piping; or

(b) The cargo tank discharge valves required by 2-3.15.1 are arranged to be normally closed and to open only when the brakes are set and the pump is engaged.

2-3.15.6 Hose shall be connected to rigid piping or coupled to the hose reel in a manner that prevents kinks or undue bending action or mechanical stress on the hose or hose couplings.

2-3.15.7 Aircraft fuel servicing vehicles shall have an integral system or device that prevents the vehicle from being moved unless all fueling nozzles and hydrant couplers are properly stowed and mechanical lifts are lowered to their stowed position.

2-3.16 Tests.

2-3.16.1 Cargo tanks, at the time of manufacture, shall be tested by a minimum air or hydrostatic pressure of 5 psi (24.4 kg/m^2) applied to the whole tank (or each compartment thereof if the tanks are compartmented). Such pressure shall be maintained for a period of at least 5 minutes during which, if the test is by air pressure, the entire exterior surface of all joints shall be coated with a solution of soap and water, heavy oil, or other substance that causes foaming or bubbling that indicates the presence of leaks. Hydrostatic pressure, if used, shall be gauged at the top of the tank. The tank shall be inspected at the joints for the issuance of liquid to indicate leaks. Any leakage discovered by either of the methods described, or by any other method, shall be considered evidence of failure to meet these requirements.

2-3-16.2

At the time of manufacture, the section of the fuel dispensing system that is under pressure during service shall be subjected to a hydrostatic test pressure equal to 150 percent of the working pressure of the system for at least 30 minutes and shall be proven tight before it is placed in service. Hose connections shall be permitted to be plugged during this test.

2-3.17 Product Identification Signs.

Each aircraft fuel servicing vehicle shall have a sign on each side and the rear to identify the product. The sign shall have letters at least 3 in. (75 mm) high and shall be of a color contrasting sharply with the sign background for visibility. The word "FLAMMABLE" and the name of the product carried, such as "JET A," "JET B," "GASOLINE," or "AVGAS" shall appear on the sign.

2-3.18 Loading.

2-3.18.1 No cargo tank or compartment shall be loaded to the point where it is liquid full. The ullage expansion space shall not be less than 1 percent of the volume of the tank compartment. Where local climatic conditions warrant, the ullage expansion space shall be increased to prevent leakage or overflow from expansion of the contents due to a rise in atmospheric temperature or direct exposure to the sun.

2-3.18.2 A heat-actuated shutoff valve shall be provided in the piping immediately upstream of the loading hose or swing arm connection.

2-3.19 Top Loading.

2-3.19.1 Drop tubes used in top loading or overhead loading of tank vehicles shall be designed to minimize turbulence. Drop tubes shall be metallic.

2-3.19.2 Fixed drop tubes permanently mounted in the vehicle tank shall extend to the bottom of the tank or to the inside of the sump to maintain submerged loading and avoid splashing of the fuel.

2-3.19.3 Drop tubes attached to loading assemblies extending into the vehicle tank shall extend to the bottom of the tank and shall be maintained in that position until the tank is loaded to provide submerged loading and avoid splashing or free fall of fuel through the tank atmosphere.

2-3.19.4 Loading arms shall be counterbalanced properly.

2-3.19.5 A deadman control shall be provided and located so that the operator can observe the liquid level in the tank as it fills.

2-3.20 Bottom Loading.

2-3.20.1 Loading hose shall conform to the requirements of Section 2-2. Swivel connections shall be provided at each end of the hose to allow free movement to compensate for changes in the position of the vehicle connection during loading.

2-3.20.2 Swinging loading arms shall be counterbalanced properly. Swivel joints shall be used to allow free movement and to compensate for changes in the attitude of the vehicle during loading.

2-3.20.3 The connection between the tank truck and the arm or hose shall be a dry-break coupler that cannot be opened until it is engaged to the vehicle tank adapter. It shall not be possible to disconnect the hose coupler from the tank vehicle connection until the internal valves of the vehicle adapter and coupler are fully closed.

2-3.20.4* The bottom loading fitting of the tank vehicle shall be a spring-loaded check valve that remains in a closed position until opened by connecting the coupler.

2-3.20.5 Aircraft fuel servicing vehicles shall incorporate an integral brake interlock system that prevents the vehicle from being moved until the bottom loading coupler has been disconnected from the vehicle.

2-3.20.6 The supply piping terminating at the loading hose or swing arm shall be supported to carry the loads imposed.

2-3.20.7 The filling of the vehicle cargo tank shall be controlled by a deadman control so that a fueling operator can monitor the operation while activating the control. In addition, a float-actuated shutoff or other automatic sensing device shall be provided. Any liquid bled from a sensing device during loading shall be piped to the bottom of the cargo tank.

2-3.20.8 The fill pipe and valving on bottom-loaded tank vehicles shall be arranged to prevent fuel spray and turbulence in the cargo tank.

2-3.21 Emergency Remote Control Stations.

2-3.21.1 Each tank vehicle loading station shall be provided with an emergency fuel shutoff system. This requirement is in addition to the deadman control required by 2-3.19.5 for top loading and by 2-3.20.7 for bottom loading. It shall be the purpose of this system to shut down the flow of fuel in the entire system or in sections of the system if an emergency occurs. This system shall be of a fail-safe design.

2-3.21.2 Each emergency fuel shutoff station location shall be placarded “EMERGENCY FUEL

SHUTOFF" in letters at least 2 in. (50 mm) high. The method of operation shall be indicated by an arrow or by the word "PUSH" or "PULL," as appropriate. Any action necessary to gain access to the shutoff device (e.g., "BREAK GLASS") shall be shown clearly. Lettering shall be of a color contrasting sharply with the placard background for visibility. Placards shall be weather resistant, shall be located at least 7 ft (2.1 m) above grade, and shall be positioned so that they can be seen readily from a distance of at least 25 ft (7.6 m).

2-4 Airport Fuel Systems.

2-4.1 Design Approval.

Work shall not be started on the construction or alteration of an airport fuel system until the design, plans, and specifications have been approved by the authority having jurisdiction.

2-4.2 System Approval.

The authority having jurisdiction shall inspect and approve the completed system before it is put into service.

2-4.3 General Requirements.

2-4.3.1 Each installation planned shall be designed and installed in conformity with the requirements of this standard and with any additional fire safety measures deemed necessary by the authority having jurisdiction.

2-4.3.2 The system and each of its components shall be designed for the working pressure of the system.

2-4.3.3 The emergency fuel shutoff system shall be designed and installed as an integral part of the airport fuel system. Operating controls for emergency fuel shutoff of the system shall be located to be accessible readily and safely in the event of an accident or spill.

2-4.3.4 In establishing each aircraft fuel dispensing location, consideration shall be given to the accessibility of the location in an emergency by fire-fighting personnel and equipment.

2-4.4 Fuel Storage Tanks.

2-4.4.1* Fuel storage tanks shall conform to the applicable requirements of NFPA 30, *Flammable and Combustible Liquids Code*.

2-4.4.2 The authority having jurisdiction shall determine the clearances required from runways, taxiways, and other aircraft movement and servicing areas to any aboveground fuel storage structure or fuel transfer equipment with due recognition given to national and international standards establishing clearances from obstructions. Tanks located in designated aircraft movement areas or aircraft servicing areas shall be underground or mounded over with earth. Vents from such tanks shall be constructed in a manner to preclude collision hazards with operating aircraft. Aircraft operators shall be consulted regarding the height and location of such vents to avoid venting flammable vapors in the vicinity of ignition sources, including operating aircraft and automotive equipment permitted in the area.

2-4.5 Emergency Fuel Shutoff Systems.

2-4.5.1 Each fuel system, as required by 2-4.3.3, shall have means for quickly and completely shutting off the flow of fuel in an emergency. This requirement is in addition to the requirement in 2-1.7 for deadman control of fuel flow.

2-4.5.2* The method of fuel transfer (gravity, pumping, or use of hydraulic or inert gas pressure) shall be considered in the design of the emergency fuel shutoff system and the location of the emergency fuel shutoff valve.

2-4.5.3 The emergency fuel shutoff system shall include shutoff stations located outside of probable spill areas and near the route that normally is used to leave the spill area or to reach the fire extinguishers provided for the protection of the area.

2-4.5.4* At least one emergency shutoff control station shall be conveniently accessible to each fueling position.

2-4.5.5 The emergency fuel shutoff system shall be designed so that operation of a station shuts off fuel flow to all hydrants that have a common exposure.

2-4.5.6 Emergency fuel shutoff systems shall be designed so that they shut off the flow of fuel if the operating power fails.

2-4.5.7 Each emergency fuel shutoff station shall be placarded "EMERGENCY FUEL SHUTOFF" in letters at least 2 in. (50 mm) high. The method of operation shall be indicated by an arrow or by the word "PUSH" or "PULL," as appropriate. Any action necessary to gain access to the shutoff device (e.g., "BREAK GLASS") shall be shown clearly. Lettering shall be of a color contrasting sharply with the placard background for visibility. Placards shall be weather resistant, shall be located at least 7 ft (2.1 m) above grade, and shall be positioned so that they can be seen readily from a distance of at least 25 ft (7.6 m). Valves used to shut off a hydrant for maintenance purposes shall not have placards that could create confusion in an emergency.

2-4.6 Transfer Piping.

2-4.6.1 Underground piping shall be used in the vicinity of aircraft movement areas unless the piping is protected by a substantial barrier guard. Piping shall be protected by suitable sleeves or casings to protect the pipe from shock hazards where it crosses sewer manholes, service tunnels, catch basins, or other underground services. Piping shall be laid on firm supports using clean, noncorrosive backfill.

2-4.6.2 Transfer piping located within buildings not specifically designed for the purpose of fuel transfer shall be located within a steel casing of a pressure rating equal to that of the carrier pipe. This casing shall extend beyond the building and terminate at a low point(s) with an automatic leak detection system. The casing shall be capable of being drained to a safe location.

2-4.6.3 Fuel piping that runs under a building or a passenger concourse shall be protected by a steel casing that encloses only the piping.

2-4.6.4 Piping, valves, and fittings shall be of metal, suitable for aviation fuel service, and designed for the working pressure and mechanically and thermally produced structural stresses to which they could be subjected and shall comply with ANSI B31.3, *Chemical Plant and Petroleum Refinery Piping.* Deviations from ANSI B31.3 can be authorized by the authority having jurisdiction where engineering data can be presented to justify such deviations.

2-4.6.5 Cast-iron, copper, and galvanized steel piping, valves, and fittings shall not be permitted. Ductile iron valves shall be permitted.

2-4.6.6 Aluminum piping, valves, and fittings shall be used only where specifically approved by the authority having jurisdiction.

2-4.6.7 In the selection of pipe, valves, and fittings, the following shall be considered:

(a) Working pressure;

(b) Bending and mechanical strength requirements (including settlement);

(c) Internal and external corrosion;

(d) Impact stresses;

(e) Method of system fabrication and assembly;

(f) Location of piping and accessibility for repair or replacement;

(g) Exposure to mechanical, atmospheric, or fire damage;

(h) Expected period of service and effect of future operations.

2-4.6.8 Gaskets in flanged connections shall resist fire temperatures for a duration comparable to the temperature resistance of the flange and bolts.

2-4.6.9 Allowances shall be made for thermal expansion and contraction by the use of pipe bends, welded elbows, or other flexible design. Pressure relief valves shall be provided in lines that can be isolated.

2-4.6.10 Welded joints shall be made by qualified welders in accordance with the standards of the American Welding Society and ANSI B31.3, *Chemical Plant and Petroleum Refinery Piping*.

2-4.6.11* Isolation valves or devices shall be provided to facilitate dismantling portions of the fueling system. These valves shall be capable of being locked closed.

2-4.6.12 Buried flanges and valves shall not be permitted.

2-4.7 Fuel Flow Control.

2-4.7.1 Hydrant valves shall be designed so that the flow of fuel shall shut off when the hydrant coupler is closed. Hydrant valves shall be of the self-closing, dry-break type.

2-4.7.2 The flow control valve shall be an integral part of the hydrant valve or coupler. The fuel control valve shall be arranged so that it is not rendered inoperative by a surface accident, spill, or malfunction and shall shut off the flow of fuel if the operating energy fails. The fuel control system shall be designed to minimize overshoot. The system shall be designed to shut off fuel flow quickly and effectively, even if there is a reduction of pressure downstream of the flow control valve such as could result from a major line or hose break. A screen shall be provided ahead of the valve to trap foreign material that could interfere with complete closure of the valve. The hydrant valve that allows the flow of fuel to the aircraft shall have a deadman control. The use of any means that allows fuel to flow without the operator activating this control shall not be permitted. The deadman control shall be arranged so that the fueling operator can observe the operation while activating the control.

2-4.7.3* The pressure of the fuel delivered to the aircraft shall be automatically controlled so that it is not higher than that specified by the manufacturer of the aircraft being serviced.

2-4.8 Filter Vessels.

All sections of the filtering system shall have electrical continuity with adjoining piping and equipment. In freezing climates, filter separator sumps and associated piping that could contain water shall be protected to prevent freezing and bursting. Heaters shall be constructed of noncorrosive materials.

2-4.9 Electrical Equipment.

All electrical equipment and wiring shall comply with the requirements of NFPA 70, *National Electrical Code*, Article 515, utilizing the Class I liquids requirements for all applications.

2-4.10 Fuel Servicing Hydrants, Pits, and Cabinets.

2-4.10.1 Piping, valves, meters, filters, air eliminators, connections, outlets, fittings, and other components shall be designed to meet the working pressure requirements of the system.

2-4.10.2 Fueling hydrants and fueling pits that are recessed below a ramp or apron surface and are subject to vehicle or aircraft traffic shall be fitted with a cover designed to sustain the load of vehicles or aircraft that taxi over all or part of them.

2-4.10.3 Fueling hydrants, cabinets, and pits shall be located at least 50 ft (15.2 m) from any terminal building, hangar, service building, or enclosed passenger concourse (other than loading bridges).

2-4.11 Drainage.

2-4.11.1 Aircraft servicing ramps or aprons shall be sloped and drained in accordance with NFPA 415, *Standard on Aircraft Fueling Ramp Drainage*. The ramp or apron shall slope away from the rim or edge of fueling hydrants or fueling pits to prevent flooding.

2-4.11.2 Fueling hydrant boxes or fueling pits that are connected to a ramp drainage system shall be fitted with vapor-sealing traps.

2-4.12* Cathodic Protection.

Systems provided with cathodic protection shall have appropriate signs, located at points of entry, warning against separation of units without prior deenergization or without proper jumpers across the sections to be disconnected. Isolation flanges shall be installed as required to separate components protected by a cathodic system from those required to be grounded for other electrical requirements.

2-4.13 Hydrostatic Test.

After completion of the installation (including fill and paving) the airport fuel systems shall be subjected to a temperature-compensated hydrostatic test pressure equal to 150 percent of the system working pressure for at least 4 hours and shall be proven tight before they are placed into service.

2-5 Fueling at Rooftop Heliports.

Fueling on rooftop heliports shall be permitted only where approved by the authority having jurisdiction.

2-5.1 General Limitations.

2-5.1.1 In addition to the special requirements in this chapter, the heliport shall comply with the requirements of NFPA 418, *Standard for Heliports*.

2-5.1.2 Facilities for dispensing fuel with a flash point below 100°F (37.8°C) shall not be permitted at any rooftop heliport.

2-5.2 Fueling Facilities.

2-5.2.1 In addition to the special requirements of this chapter, the fuel storage, piping, and dispensing system shall comply with the requirements of NFPA 30, *Flammable and Combustible Liquids Code*, and with applicable portions of this standard.

2-5.2.2 The entire system shall be designed so that no part of the system is subjected to pressure above its working pressure.

2-5.2.3 The fuel storage system shall be located at or below ground level.

2-5.3 Pumps.

2-5.3.1 Pumps shall be located at or below ground level. Relay pumping shall not be permitted.

2-5.3.2 Pumps installed outside of buildings shall be located not less than 5 ft (1.5 m) from any building opening. They shall be substantially anchored and protected against physical damage from collision.

2-5.3.3 Pumps installed within a building shall be in a separate room with no opening into other portions of the building. The pump room shall be adequately ventilated. Electrical wiring and equipment shall conform to the requirements of NFPA 70, *National Electrical Code*, Article 515.

2-5.4 Piping.

Piping above grade shall be steel and, unless otherwise approved by the authority having jurisdiction, shall be suitably cased or shall be installed in a duct or chase. Such piping duct or chase shall be constructed so that a piping failure does not result in the entry of fuel liquid or vapor entering the building. All pipe casings, ducts, and chases shall be drained. Piping shall be anchored and shall be protected against physical damage for a height of at least 8 ft (2.4 m) above the ground. An isolation valve shall be installed on the suction and discharge piping of each pump. In addition, a check valve shall be installed at the base of each fuel piping riser to automatically prevent the reverse flow of the fuel into the pump room in the event of pump seal failure, pipe failure, or other malfunction. (*See 2-4.6.*)

2-5.4.1 Piping within buildings shall comply with 2-4.6.2.

2-5.4.2 Piping above grade exterior to buildings shall be of steel. Piping shall be located within a steel casing. The pressure rating of the pipe casing shall be equal to that of the carrier pipe. The casing shall be capable of being drained to a safe location. An automatic leak detection system shall be provided at the casing low point(s).

2-5.4.3 Piping shall be anchored and shall be protected against physical damage for a height of at least 8 ft (2.4 m) above the ground.

2-5.4.4 An isolation valve shall be installed on the suction and discharge piping of each pump. In addition, a check valve shall be installed at the base of each fuel piping riser to automatically prevent the reverse flow of fuel into the pump room in the event of a pump seal failure, pipe failure, or other malfunction.

2-5.5 Nozzles.

2-5.5.1 Overwing nozzles shall conform to 2-3.15.2.

2-5.5.2 Underwing nozzles shall conform to 2-3.15.3.

2-5.6 Hose.

Hose shall comply with the requirements of Section 2-2.

2-5.7 Static Electricity.

The provisions of 2-1.2 shall apply, as appropriate, to guard against electrostatic hazards during helicopter fuel servicing operations.

2-5.8 Deadman Control.

Each fuel dispensing hose shall have a deadman-controlled fuel shutoff conforming to the requirements of 2-1.7 and 2-1.8.

2-5.9 Emergency Fuel Shutoff Stations.

2-5.9.1 A system shall be provided to completely shut off the flow of fuel in an emergency. The system shall shut off the fuel at the ground level. The emergency fuel shutoff controls shall be in addition to the normal operating controls for the pumps and deadman control.

2-5.9.2 At least two emergency fuel shutoff stations located on opposite sides of the heliport at exitways or at similar locations shall be provided. An additional emergency fuel shutoff station shall be located at ground level and shall be near, but at least 10 ft (3 m) from, the pumps.

2-5.9.3 Each emergency fuel shutoff station location shall be placarded "EMERGENCY FUEL SHUTOFF" in letters at least 2 in. (50 mm) high. The method of operation shall be indicated by an arrow or by the word "PUSH" or "PULL," as appropriate. Any action necessary to gain access to the shutoff device (e.g., "BREAK GLASS") shall be shown clearly. Lettering shall be of a color contrasting sharply with the placard background for visibility. Placards shall be weather resistant, shall be conspicuously located, and shall be positioned so that they can be seen readily from a distance of at least 25 ft (7.6 m).

2-5.10 Fire Protection.

Fire protection shall conform to the requirements of NFPA 418, *Standard for Heliports*.

2-5.11 Personnel Training.

All heliport personnel shall be trained in the operation of emergency fuel shutoff controls and in the use of the available fire extinguishers.

2-6 Self-service Aircraft Fueling.

2-6.1

Self-service fueling shall be permitted, subject to the approval of the authority having jurisdiction.

2-6.2 Fueling Facilities.

In addition to the special requirements of this chapter, the fuel storage, piping, and dispensing system shall comply with the requirements of NFPA 30, *Flammable and Combustible Liquids Code*, and with applicable portions of this standard.

2-6.3 Dispensing Devices.

2-6.3.1 Listed or approved dispensing devices shall be used.

2-6.3.2 Access to dispensing equipment shall be controlled by means of mechanical or electronic devices designed to resist tampering and to prevent access or use by unauthorized persons.

2-6.3.3 Dispensing devices shall have a listed or approved emergency shutoff valve, incorporating a fusible link or other thermally actuated device designed to close automatically in case of fire. This valve also shall incorporate a shear section that automatically shuts off the flow of fuel due to severe impact. This valve shall be rigidly mounted at the base of the dispenser in accordance with the manufacturer's instructions.

2-6.3.4 Dispensing devices shall be located on an island to protect against collision damage or shall be suitably protected with pipe bollards or other suitable protection.

2-6.3.5* Dispensing devices or cabinets shall be designed so that a proper bond between the aircraft and the fueling equipment can be established in accordance with Section 3-4.

2-6.4

Hose shall comply with the requirements of Section 2-2. Two or more lengths of hose shall not be coupled together.

2-6.5 Nozzles.

2-6.5.1 Overwing nozzles shall conform to 2-3.15.2.

2-6.5.2 Underwing nozzles shall conform to 2-3.15.3.

2-6.6 Emergency Fuel Shutoff System.

2-6.6.1 A system conforming with 2-4.5 shall be provided to shut off the flow of fuel completely in an emergency. The emergency fuel shutoff controls shall be in addition to the normal operating controls for the dispenser and deadman control.

2-6.6.2 The controls shall be designed to allow only authorized personnel to reset the system after an emergency fuel shutoff.

2-6.6.3 The emergency fuel shutoff controls shall be installed in a location acceptable to the authority having jurisdiction and shall be more than 20 ft (7 m) but less than 100 ft (30 m) from the dispensers.

2-6.7

A clearly identified means to notify the fire department shall be provided and shall be located in the immediate vicinity of each emergency fuel shutoff control.

2-6.8

Each facility shall have a minimum of one fire extinguisher with a rating of at least 20-B:C located at the dispenser and one fire extinguisher with a rating of at least 20-B:C at each emergency fuel shutoff control.

2-6.9

In addition to the warning signs specified in 2-4.5.7 and 3-8.1, emergency instructions shall be conspicuously posted in the dispensing area and at the emergency fuel shutoff control and shall provide the address of the site and incorporate the following or equivalent wording:

EMERGENCY INSTRUCTIONS:

In case of fire or spill:
1. Use emergency fuel shutoff.
2. Report accident by calling (specify local fire emergency reporting number) on phone.
3. Report address of site (list address of site here).

2-6.10 Operating Instructions.

Operating instructions shall be posted. The instructions shall include the proper operation and use of all equipment, correct bonding procedures, the procedures that are to be employed to dispense fuel safely, the location and use of the emergency fuel shutoff controls, the use of the available fire extinguishers, and the procedures to be used in the event of an emergency.

Chapter 3 Operations

3-1 General.

3-1.1

Only authorized personnel trained in the safe operation of the equipment they use, in the operation of emergency controls, and in the procedures to be followed in an emergency shall fuel or defuel aircraft.

3-1.2

Where a valve or electrical device is used for isolation during maintenance or modification of the fuel system, it shall be tagged/locked. The tag/lock shall not be removed until the operation is completed.

3-2* Prevention and Control of Spills.

3-2.1

Fuel servicing equipment shall comply with the requirements of this standard and shall be maintained in safe operating condition. Leaking or malfunctioning equipment shall be removed from service.

3-2.2

Fuel nozzles shall not be dragged along the ground.

3-2.3

Pumps, either hand operated or power operated, shall be used where aircraft are fueled from drums. Pouring or gravity flow shall not be permitted from a container with a capacity of more than 5 gal (18.9 L).

3-2.4

Where a spill is observed, the fuel servicing shall be stopped immediately by release of the deadman controls. In the event that a spill continues, the equipment emergency fuel shutoff shall be actuated. In the event that a spill continues from a hydrant system, the system emergency fuel shutoff shall be actuated. The supervisor shall be notified at once, and the operation shall not be resumed until the spill has been cleared and conditions are determined to be safe.

3-2.5

The airport fire crew shall be notified if a spill covers over 10 ft (3 m) in any direction or is over 50 ft^2 (5 m^2) in area, continues to flow, or is otherwise a hazard to persons or property. The spill shall be investigated to determine the cause, to determine whether emergency procedures were properly carried out, and to determine the necessary corrective measures.

3-2.6

Transferring fuel by pumping from one tank vehicle to another tank vehicle within 200 ft (61 m) of an aircraft shall not be permitted.

3-2.7

Not more than one tank vehicle shall be permitted to be connected to the same aircraft fueling manifold.

Exception: Where means are provided to prevent fuel from flowing back into a tank vehicle because of a difference in pumping pressure.

3-3 Emergency Fuel Shutoff.

3-3.1

Access to emergency fuel shutoff control stations shall be kept clear at all times.

3-3.2

A procedure shall be established to notify the fire department serving the airport in the event of a control station activation.

3-3.3

If the fuel flow stops for any reason, it first shall be presumed that an emergency fuel shutoff system has been actuated. The cause of the shutoff shall be corrected before fuel flow is resumed.

3-3.4

Emergency fuel shutoff devices shall be operationally checked at least every 3 months.

3-3.5

Suitable records shall be kept of tests required by this section.

3-4* Bonding.

3-4.1

Prior to making any fueling connection to the aircraft, the fueling equipment shall be bonded to the aircraft by use of a cable, thus providing a conductive path to equalize the potential between the fueling equipment and the aircraft. The bond shall be maintained until fueling connections have been removed, thus allowing separated charges that could be generated during the fueling operation to reunite.

3-4.2

In addition to the above, where fueling overwing, the nozzle shall be bonded with a nozzle bond cable having a clip or plug to a metallic component of the aircraft that is metallically connected to the tank filler port. The bond connection shall be made before the filler cap is removed. If there is no plug receptacle or means for attaching a clip, the operator shall touch the filler cap with the nozzle spout before removing the cap in order to equalize the potential between the nozzle and the filler port. The spout shall be kept in contact with the filler neck until the fueling is completed.

3-4.3*

Where a funnel is used in aircraft fueling, it shall be kept in contact with the filler neck as well as the fueling nozzle spout or the supply container to avoid the possibility of a spark at the fill opening. Only metal funnels shall be used.

3-4.4

Where a hydrant servicer or cart is used for fueling, the hydrant coupler shall be connected to the hydrant system prior to bonding the fuel equipment to the aircraft.

3-4.5

Bonding and fueling connections shall be disconnected in the reverse order of connection.

3-4.6

Conductive hose shall be used to prevent electrostatic discharge but shall not be used to accomplish required bonding.

3-5 Operation of Aircraft Engines and Heaters.

3-5.1

Fuel servicing shall not be performed on a fixed wing aircraft while an onboard engine is operating. (*See Section 3-21.*)

Exception: In an emergency resulting from the failure of an onboard auxiliary power unit on a jet aircraft and in the absence of suitable ground support equipment, a jet engine mounted at the rear of the aircraft or on the wing on the side opposite the fueling point shall be permitted to be operated during fueling to provide power, provided that the operation follows written procedures approved by the authority having jurisdiction.

3-5.2

Combustion heaters on aircraft (e.g., wing and tail surface heaters, integral cabin heaters) shall not be operated during fueling operations.

3-6 Internal Combustion Engine Equipment Around Aircraft (Other than Aircraft Fuel Servicing Vehicles).

3-6.1

Equipment, other than that performing aircraft servicing functions, shall not be permitted within 50 ft (15 m) of aircraft during fuel servicing operations.

3-6.2

Equipment performing aircraft servicing functions shall not be positioned within a 10-ft (3-m) radius of aircraft fuel system vent openings.

3-6.3

During overwing aircraft fuel servicing where aircraft fuel system vents are located on the upper wing surface, equipment shall not be positioned under the trailing edge of the wing.

3-7* Electrical Equipment Used on Aircraft Servicing Ramps.

3-7.1

Battery chargers shall not be connected, operated, or disconnected while fuel servicing is performed on the aircraft.

3-7.2*

Aircraft ground-power generators or other electrical ground-power supplies shall not be connected or disconnected while fuel servicing is performed on the aircraft.

3-7.3

Electric tools or similar tools likely to produce sparks or arcs shall not be used while fuel servicing is performed on the aircraft.

3-7.4

Photographic equipment shall not be used within 10 ft (3 m) of the fueling equipment or the fill or vent points of aircraft fuel systems.

3-7.5

Battery-powered vehicle equipment shall not be operated within 10 ft (3 m) of fueling equipment or spills.

3-7.6

Communication equipment used during aircraft fuel servicing operations within 10 ft (3 m) of the fueling equipment or the fill or vent points of aircraft fuel systems shall be intrinsically safe in accordance with UL 913, *Standard for Intrinsically Safe Apparatus and Associated Apparatus for Use in Class I, II, and III Division 1, Hazardous (Classified) Locations*.

3-8 Open Flames on Aircraft Fuel Servicing Ramps.

3-8.1

Entrances to fueling areas shall be posted with “no smoking” signs.

3-8.2

Open flames on aircraft fuel servicing ramps or aprons within 50 ft (15 m) of any aircraft fuel servicing operation or fueling equipment shall be prohibited.

3-8.3

The category of open flames and lighted open-flame devices shall include, but shall not be limited to, the following:

(a) Lighted cigarettes, cigars, pipes;

(b) Exposed flame heaters, liquid, solid, or gaseous devices, including portable and wheeled gasoline or kerosene heaters;

(c) Heat-producing, welding, or cutting devices and blowtorches;

(d) Flare pots or other open-flame lights.

3-8.4

The authority having jurisdiction might establish other locations where open flames and open-flame devices shall not be permitted.

3-8.5

Personnel shall not carry lighters or matches on their person while engaged in fuel servicing operations.

3-8.6

Lighters or matches shall not be permitted on or in fueling equipment.

3-9* Lightning Precautions.

3-9.1

Fuel servicing operations shall be suspended where there are lightning flashes in the immediate vicinity of the airport.

3-9.2

A written procedure shall be established to set the criteria for where fueling operations must be suspended at each airport as approved by the fueling agent and the airport authority.

3-10 Aircraft Fuel Servicing Locations.

3-10.1

Aircraft fuel servicing shall be performed outdoors. Aircraft fuel servicing incidental to aircraft fuel system maintenance operations shall comply with the requirements of NFPA 410, *Standard on Aircraft Maintenance.*

3-10.2*

Aircraft being fueled shall be positioned so that aircraft fuel system vents or fuel tank openings are not closer than 25 ft (8 m) from any terminal building, hangar, service building, or enclosed passenger concourse other than a loading walkway. Aircraft being fueled shall not be positioned so that the vent or tank openings are within 50 ft (15 m) of any combustion and ventilation air-intake to any boiler, heater, or incinerator room.

3-10.3

Accessibility to aircraft by emergency fire equipment shall be established for aircraft fuel servicing positions.

3-11 Aircraft Occupancy During Fuel Servicing Operations.

3-11.1

If passengers remain onboard an aircraft during fuel servicing, at least one qualified person trained in emergency evacuation procedures shall be in the aircraft at or near a door at which there is a passenger loading walkway, integral stairs that lead downward, or a passenger loading stair or stand. A clear area for emergency evacuation of the aircraft shall be maintained at not less than one additional exit. Aircraft operators shall establish specific procedures covering emergency evacuation under such conditions for each type of aircraft they operate. All "no smoking" signs shall be displayed in the cabin(s) and the no smoking rule shall be enforced.

3-11.2

For each aircraft type, operators shall determine the areas through which it could be hazardous for boarding or deplaning passengers to pass while the aircraft is being fueled. Controls shall be established so that passengers avoid such areas.

3-12 Positioning of Aircraft Fuel Servicing Vehicles.

3-12.1

Aircraft fuel servicing vehicles shall be positioned so that a clear path of egress from the aircraft for fuel servicing vehicles shall be maintained.

3-12.2

The propulsion or pumping engine of aircraft fuel servicing vehicles shall not be positioned under the wing of the aircraft during overwing fueling or where aircraft fuel system vents are located on the upper wing surface. Aircraft fuel servicing vehicles shall not be positioned within a 10-ft (3-m) radius of aircraft fuel system vent openings.

3-12.3

Parking brakes shall be set on fuel servicing vehicles before operators leave the vehicle cab.

3-13* Portable Fire Extinguishers.

3-13.1

During fueling operations, fire extinguishers shall be available on aircraft servicing ramps or aprons.

3-13.2

Each aircraft fuel servicing tank vehicle shall have two listed fire extinguishers, each having a rating of at least 20-B:C, with one extinguisher mounted on each side of the vehicle.

3-13.3

There shall be one listed fire extinguisher having a rating of at least 20-B:C installed on each hydrant fuel servicing vehicle.

3-13.4

Where the open hose discharge capacity of the aircraft fueling system or equipment is more than 200 gal per minute (750 L/min), at least one listed wheeled extinguisher having a rating of not less than 80-B:C and a minimum capacity of 125 lb (55 kg) of agent shall be provided.

3-13.5*

Extinguishers shall be kept clear of elements such as ice and snow. Extinguishers located in enclosed compartments shall be readily accessible and their location shall be marked clearly in letters at least 2 in. (50 mm) high.

3-13.6*

Fuel servicing personnel shall be trained in the use of the available fire extinguishing equipment they might be expected to use.

3-14 Defueling.

3-14.1

The transfer of fuel from an aircraft to a tank vehicle through a hose generally is similar to fueling, and the same requirements shall apply. In addition, each operator shall establish procedures to prevent the overfilling of the tank vehicle, which is a special hazard when defueling.

3-14.2

Where draining residual fuel from aircraft tanks incidental to aircraft fuel system maintenance, testing, manufacturing, salvage, or recovery operations, the procedures of NFPA 410, *Standard on Aircraft Maintenance*, shall apply.

3-15 Deadman Control Monitoring.

3-15.1

The fueling operator shall monitor the panel of the fueling equipment and the aircraft control panel during pressure fueling or shall monitor the fill port during overwing fueling.

3-15.2

Fuel flow shall be controlled by use of a deadman control device. The use of any means that defeats the deadman control shall be prohibited.

3-16* Aircraft Fueling Hose.

3-16.1

Aircraft fueling hose shall be inspected before use each day. The hose shall be extended as it normally would be for fueling and checked for evidence of blistering, carcass saturation or separation, cuts, nicks, or abrasions that expose reinforcement material, and for slippage, misalignment, or leaks at couplings. If coupling slippage or leaks are found, the cause of the problem shall be determined. Defective hose shall be removed from service.

3-16.2

At least once each month the hose shall be completely extended and inspected as required in 3-16.1. The hose couplings and the hose shall be examined for a length approximately 12 in. (305 mm) adjacent to the couplings. Structural weakness shall be checked by pressing the hose in this area around its entire circumference for soft spots. Hoses that show evidence of soft spots shall be removed from service. The nozzle screens shall be examined for rubber particles. The presence of such particles indicates possible deterioration of the interior, and the hose shall be removed from service. With the hose still completely extended, it shall be checked at the working pressure of the fueling equipment to which it is attached. Any abnormal twisting or ballooning during this test indicates a weakening of the hose carcass, and the hose shall be removed from service.

3-16.3

A hose assembly that has been subjected to abuse, such as severe end-pull, flattening or crushing by a vehicle, or sharp bending or kinking, shall be removed from service. It shall be hydrostatically tested prior to use. (*See 2-2.2.1.*)

3-16.4

If inspection shows that a portion of a hose has been damaged, the damaged portion shall be cut off and the undamaged portion recoupled. Two lengths of hose shall not be coupled together. Only couplings that are an exact match for the interior and exterior dimensions of the hose shall be used. Recoupled hose assemblies shall be hydrostatically tested. (*See 2-2.2.1*.)

3-16.5

Before any hose assembly, new or recoupled, is placed in service, it shall be visually inspected for evidence of damage or deterioration.

3-16.6

Kinks or short loops in fueling hose shall be avoided.

3-16.7

Suitable records shall be kept of required inspections and hydrostatic tests.

3-17 Maintenance of Aircraft Fuel Servicing Vehicles.

3-17.1

Aircraft fuel servicing vehicles shall not be operated unless they are in proper repair and free of accumulations of grease, oil, or other combustibles.

3-17.2

Leaking vehicles shall be removed from service, defueled, and parked in a safe area until repaired.

3-17.3

Maintenance and servicing of aircraft fuel servicing vehicles shall be performed outdoors or in a building approved for the purpose.

3-18 Parking Aircraft Fuel Servicing Tank Vehicles.

Parking areas for unattended aircraft fuel servicing tank vehicles shall be arranged to provide the following:

(a) Dispersal of the vehicles in the event of an emergency;

(b) A minimum of 10 ft (3 m) of clear space between parked vehicles for accessibility for fire control purposes;

(c) Prevention of any leakage from draining to an adjacent building or storm drain that is not suitably designed to handle fuel;

(d) A minimum of 50 ft (15 m) from any parked aircraft and buildings other than maintenance facilities and garages for fuel servicing tank vehicles.

3-19 Parking Aircraft Fuel Servicing Hydrant Vehicles.

Parking areas for unattended aircraft fuel servicing hydrant vehicles shall be arranged to provide the following:

(a) Dispersal of the vehicles in the event of an emergency;

(b) Prevention of any leakage from draining to an adjacent building or storm drain that is not suitably designed to handle fuel.

3-20 Loading of Aircraft Fuel Servicing Tank Vehicles.

3-20.1 General Requirements.

3-20.1.1 Filling of the vehicle cargo tank shall be under the observation and control of a qualified and authorized operator at all times.

3-20.1.2 The required deadman and automatic overfill controls shall be in normal operating condition during the filling operation. They shall not be blocked open or otherwise bypassed.

3-20.1.3 The engine of the tank vehicle shall be shut off before starting to fill the tank.

3-20.1.4 To prevent leakage or overflow from expansion of the contents due to a rise in atmospheric temperature or direct exposure to the sun, no cargo tank or compartment shall be loaded to the point where it is liquid full.

3-20.2 Top Loading.

3-20.2.1 Where loading tank trucks through open domes, a bond shall be established between the loading piping and the cargo tank to equalize potentials. The bond connection shall be made before the dome is opened and shall be removed only after the dome is closed.

3-20.2.2 Drop tubes attached to loading assemblies extending into the vehicle tank shall extend to the bottom of the tank and shall be maintained in that position until the tank is loaded to provide submerged loading and avoid splashing or free fall of fuel through the tank atmosphere. The flow rate into the tanks shall not exceed 25 percent of the maximum flow until the outlet is fully covered.

3-20.2.3 The level in the tank shall be visually monitored at all times during top loading.

3-20.3 Bottom Loading.

3-20.3.1 A bonding connection shall be made between the cargo tank and the loading rack before any fuel connections are made and shall remain in place throughout the loading operation.

3-20.3.2 The operator shall initiate fuel flow by means of a deadman control device.

3-20.3.3 The operator shall perform the precheck on each compartment shortly after flow has started to ensure that the automatic high-level shutoff system is functioning properly.

3-21 Rapid Refueling of Helicopters.

3-21.1

Only turbine engine helicopters fueled with Jet A or Jet A-1 fuels shall be permitted to be fueled while an onboard engine is operating.

Helicopters permitted to be fueled while an onboard engine is operating shall have all sources of ignition of potential fuel spills located above the fuel inlet port(s) and above the vents or tank openings. Ignition sources shall include, but shall not be limited to, engines, exhausts, APUs, and combustion-type cabin heater exhausts.

3-21.2

Helicopter fueling while onboard engines are operating shall be permitted only under the following conditions:

(a) An FAA-licensed helicopter pilot shall be at the aircraft controls during the entire fuel servicing process.

(b)* Passengers shall be deboarded to a safe location prior to rapid refueling operations. Where the pilot in command deems it necessary for passengers to remain onboard for safety reasons, the provisions of 3-11.1 shall apply.

(c) Passengers shall not board or deboard during rapid refueling operations.

(d) Only designated personnel, properly trained in rapid refueling operations, shall operate the equipment. Written procedures shall include the safe handling of the fuel and equipment.

(e) All doors, windows, and access points allowing entry to the interior of the helicopter that are adjacent to, or in the immediate vicinity of, the fuel inlet ports shall be closed and shall remain closed during refueling operations.

(f) Fuel shall be dispensed into an open port from approved deadman-type nozzles, with a flow rate not to exceed 60 gpm (227 L/min), or it shall be dispensed through close-coupled pressure fueling ports. Where fuel is dispensed from fixed piping systems, the hose cabinet shall not extend into the rotor space. A curb or other approved barrier shall be provided to restrict the fuel servicing vehicle from coming closer than within 10 ft (3 m) of any helicopter rotating components. If a curb or approved barrier cannot be provided, fuel servicing vehicles shall be kept 20 ft (6 m) away from any helicopter rotating components, and a trained person shall direct fuel servicing vehicle approach and departure.

3-22 Self-service Fueling.

Occupancy of the aircraft during self-service fueling shall be prohibited.

Chapter 4 Referenced Publications

4-1

The following documents or portions thereof are referenced within this standard and shall be considered part of the requirements of this document. The edition indicated for each reference is the current edition as of the date of the NFPA issuance of this document.

4-1.1 NFPA Publications.

National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.

NFPA 10, *Standard for Portable Fire Extinguishers*, 1994 edition.

NFPA 30, *Flammable and Combustible Liquids Code*, 1993 edition.

NFPA 70, *National Electrical Code*, 1996 edition.

NFPA 385, *Standard for Tank Vehicles for Flammable and Combustible Liquids*, 1990 edition.

NFPA 410, *Standard on Aircraft Maintenance*, 1994 edition.

NFPA 415, *Standard on Aircraft Fueling Ramp Drainage*, 1992 edition.

NFPA 418, *Standard for Heliports*, 1995 edition.

4-1.2 Other Publications.

4-1.2.1 ANSI Publication. American Standards Institute, 1430 Broadway New York, NY 10018.

ANSI B31.3, *Chemical Plant and Petroleum Refinery Piping*, 1993.

4-1.2.2 API Publication. American Petroleum Institute, 1220 L Street NW, Washington, DC 20005.

API BULL 1529, *Aviation Fueling Hose*, 1989.

4-1.2.3 ASTM Publication. American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103.

ASTM D 380, *Standard Test Methods for Rubber Hose*, 1994.

4-1.2.4 AWS Publication. American Welding Society, Inc., 550 NW LeJeune Road, PO Box 351040, Miami, FL 33135.

AWS A5.10, *Specification for Bare Aluminum and Aluminum Alloy Welding Electrodes and Rods*, 1992.

4-1.2.5 BS Publication. British Standards Institution, Linfood Wood, Milton Keynes, Bucks, MK14 6LE, United Kingdom.

BS 3158, *Rubber Hoses and Hose Assemblies for Aircraft Ground Fueling and Defueling*, 1985.

4-1.2.6 UL Publication. Underwriters Laboratories Inc., 333 Pfingsten Road, Northbrook, IL 60062.

UL 913, *Standard for Intrinsically Safe Apparatus and Associated Apparatus for Use in Class I, II, and III Division 1, Hazardous (Classified) Locations*, 1988.

Appendix A Explanatory Material

This Appendix is not a part of the requirements of this NFPA document but is included for informational purposes only.

A-1-2 Fire Hazards in Aircraft Fuel Servicing.

(a) Aircraft fuel servicing involves the transfer of a flammable or combustible liquid fuel between a bulk storage system and the fuel tanks of an aircraft. It includes both fueling and defueling. The transfer is usually accomplished by using a tank vehicle, a hydrant vehicle, a fuel servicing cabinet, or a fueling pit. Drums and pumps sometimes are used.

The movement of the fuel through the pumps, piping, and filters of the transfer system causes the fuel to be charged electrostatically.

If the charge on the fuel is sufficiently high when it arrives at the fuel tank, a static spark could occur that might ignite the fuel vapor.

(b) During overwing fueling, the fuel is discharged into an opening in the aircraft fuel tank using a hose with a hand-held nozzle. The flow and splashing of fuel causes the generation of static electricity and the production of flammable mists and vapors. Top loading of tank vehicles creates similar hazards.

(c) Underwing servicing, hydrant servicing, and bottom loading of tank vehicles use hoses or flexible connections of metal tubing or piping, as well as devices to allow temporary connection of fuel transfer lines. These methods minimize the charge generation and misting hazards associated with overwing fueling and top loading.

(d) Other potential sources of ignition that could present a hazard during aircraft fuel servicing include:

1. Operating aircraft engines, auxiliary power units, and heaters.

2. Operating automotive or other internal combustion engine servicing equipment in the vicinity.

3. Arcing of electrical circuits.

4. Open flames.

5. Energy from energized radar equipment.

6. Lightning.

(e) The autoignition temperatures of turbine fuels (*see A-1-3, "Aviation Fuel"*) are such that the residual heat of aircraft turbine engines after shutdown or the residual heat of turbine aircraft brakes following hard use can ignite such fuels if they are spilled or sprayed on these surfaces before they have cooled below the autoignition temperatures of the fuels.

(f) Aircraft fuel tank vents usually are located some distance above ground level. Under normal conditions, fuel vapors from the vents are quickly dissipated and diluted safely. Fuel spilling from the vents of an overfilled tank is a much more serious hazard. Spills resulting from leaks or equipment failure also are a hazard.

(g) Fire prevention measures in aircraft fuel servicing are directed principally toward the following:

1. Prevention of fuel spillage;

2. Elimination or control of potential ignition sources.

A-1-3 Approved.

The National Fire Protection Association does not approve, inspect, or certify any installations, procedures, equipment, or materials; nor does it approve or evaluate testing laboratories. In determining the acceptability of installations, procedures, equipment, or materials, the authority having jurisdiction may base acceptance on compliance with NFPA or other appropriate standards. In the absence of such standards, said authority may require evidence of proper installation, procedure, or use. The authority having jurisdiction may also refer to the listings or labeling practices of an organization concerned with product evaluations that is in a position to determine compliance with appropriate standards for the current production of listed items.

A-1-3 Authority Having Jurisdiction.

The phrase "authority having jurisdiction" is used in NFPA documents in a broad manner, since jurisdictions and approval agencies vary, as do their responsibilities. Where public safety is primary, the authority having jurisdiction may be a federal, state, local, or other regional department or individual such as a fire chief; fire marshal; chief of a fire prevention bureau, labor department, or health department; building official; electrical inspector; or others having statutory authority. For insurance purposes, an insurance inspection department, rating bureau, or other insurance company representative may be the authority having jurisdiction. In many circumstances, the property owner or his or her designated agent assumes the role of the authority having jurisdiction; at government installations, the commanding officer or departmental official may be the authority having jurisdiction.

A-1-3 Aviation Fuel.

The fire hazard properties of aviation fuels are best described by analyzing the following:

I. Susceptibility to or Ease of Ignition.

(a) *Flash Point.*

1. The flash point of standard grades of aviation gasoline has been established at approximately -50°F (-46°C) at sea level by the Tag closed-cup method. The flash point of JET B turbine fuel is not regulated by specification, but samples have been tested by the closed-cup method and have been found to be as low as -10°F (-23°C) at sea level. JET A or kerosene grade turbine fuels have a minimum flash point of 100°F (38°C).

2. Aviation gasoline and JET B turbine produce large volumes of vapor and are capable of forming ignitible mixtures with air even at very low temperatures. Kerosene grades of turbine fuel (JET A) do not produce ignitible mixtures with air at normal temperatures and pressures, but when a JET A turbine fuel is heated above its flash point (or exists in the form of a mist), the mixture can be ignited. This condition can develop where temperatures are 100°F (38°C) or higher.

(b) *Flammability Conditions.*

1. The lower limit represents the minimum concentration while the upper limit defines the maximum amount of fuel vapors in air that allows combustion. The generally accepted flammability range by volume for most gasolines is 1.4 percent to 7.6 percent. The average range for JET B turbine fuels is 1.16 percent to 7.63 percent. The average range for kerosene grade (JET A) turbine fuels is 0.74 percent to 5.32 percent.

2. More significant than the strict flammability range is the temperature range in which it is possible for such flammable vapor-air mixtures to form. At sea level in a storage tank, such a temperature range for aviation gasoline is approximately -50°F to 30°F (-46°C to -1°C); for JET B turbine fuels, the range is approximately -10°F to 80°F (-23°C to 27°C); and, for kerosene grade (JET A) turbine fuels, the range is approximately 100°F to 165°F (38°C to 74°C). It is evident that JET B turbine fuels represent the most serious practical hazard under normal temperature conditions.

3. Air enters as vented tanks are drained, and, during such periods, the flammable vapor conditions can change drastically. The same change occurs when the aircraft descends in altitude. These facts are important in assessing the degree of hazard that could exist in a tank containing any of these volatile products during or after such air mixing.

4. Under aircraft crash impact conditions where fuel mists are created following tank failures, all of the fuels are readily ignitible at essentially all ambient temperatures. Under these conditions, fuel in mist form presents a hazard equal to fuel in vapor form with respect to flammability limits.

(c) *Vapor Pressure.*

1. The vapor pressure of these fuels is the pressure of the vapor at any given temperature at which the vapor and liquid phases of the substance are in equilibrium in a closed container. Such pressures vary with the temperature, but, most commonly, information on hydrocarbon mixtures is obtained using the Reid method, in which the pressures are measured at 100°F (38°C) [*see ASTM D 323, Standard Test Method for Vapor Pressure of Petroleum Products (Reid Method)*]. The Reid vapor pressures of average grades of aviation gasoline have a range of 5.5 psi to 7.0 psi (38 kPa to 48 kPa). For JET B turbine fuels, the Reid vapor pressure range is 2.0 psi to 3.0 psi (14 kPa to 21 kPa). JET A (kerosene grade) turbine fuels have a Reid vapor pressure range of approximately 0.1 psi (0.7 kPa).

2. The practical significance of this characteristic of the three grades of fuel is that the standard grades of aviation gasoline do produce flammable vapors in ignitible amounts at normal temperatures and pressures. However, where these vapors are confined, the vapor-air mixture over the liquid surface most often is too rich to be ignited by sparks, since it is above the upper flammability limit. With JET B turbine fuel, due to its relatively low vapor pressure, the vapor-air mixture above the liquid surface under normal temperature and pressure conditions frequently is within the flammability range. This means that ignition of JET B turbine fuel vapors either within or exterior to a tank can cause violent combustion within the confined space if flame enters. The JET A (kerosene grade) turbine fuels do not produce flammable vapors in ignitible amounts unless the fuel temperature is above 100°F (38°C).

(d) *Autoignition Temperature.*

1. The autoignition temperature is the minimum temperature of a substance which will initiate or cause self-sustained combustion independently of any sparks or other means of ignition.

2. Under one set of test conditions, standard grades of aviation gasoline have ignition temperatures approximating 840°F (449°C). Turbine fuels have ignition temperatures among the lowest found for hydrocarbons and are considerably lower than those for aviation gasoline. For example, the autoignition temperature of a JET B turbine fuel was measured using the same test procedure at approximately 480°F (249°C). A JET A (kerosene grade) turbine fuel tested under the same method was found to have an autoignition temperature approximating 475°F (246°C). Temperatures in this range can exist for a considerable period in turbine engines after shutdown or on brake surfaces following hard use.

3. It should be noted that these temperatures are derived from reproducible laboratory test procedures, whereas, in actual field conditions, these ignition temperatures might be higher.

(e) *Distillation Range.*

1. The initial and the end boiling points of standard grades of aviation gasoline are approximately 110°F and 325°F (43°C and 163°C), respectively. The initial boiling point of JET B turbine fuels is approximately 135°F (57°C) and the end point is approximately 485°F (252°C). The only marked difference in the distillation ranges of the three fuels under consideration occurs in the JET A or kerosene grades of turbine fuels that have initial boiling points of approximately 325°F (163°C) and end points of approximately 572°F (300°C).

NOTE: Initial and end boiling points should be determined by ASTM D 86, *Standard Test Method for*

Distillation of Petroleum Products.

2. The boiling range, along with the flash points and vapor pressures of the fuels, indicates the relative volatility of the fuels; the initial and end boiling points indicate the overall volatility of a fuel through its entire distillation range; the flash point and vapor pressures measure the initial tendency of the fuel to vaporize.

II. Fire Severity After Ignition.

(a) *Heat of Combustion.*

1. The net heat of combustion of gasoline normally is quoted as approximately 19,000 Btu/lb (44.19 kJ/kg). For JET B turbine fuels, the average is approximately 18,700 Btu/lb (43.50 kJ/kg), while for the JET A (kerosene grades) of turbine fuels it is approximately 18,600 Btu/lb (43.26 kJ/kg).

2. These figures for heat of combustion clearly indicate that there is little difference in the heats of combustion for these various hydrocarbons that are of significance with regard to fire safety.

(b) *Rate of Flame Spread.*

Where fuel is spilled, there is a marked difference in the rates of flame spread over pools of JET A or kerosene grades of turbine fuel as compared with the other two types. Under these conditions, a direct relationship exists between the rate of flame spread and the vapor pressures of the materials. A report dated October 1973 entitled "An Evaluation of the Relative Fire Hazards of JET A and JET B for Commercial Flight" (N74-10709) states that the rate (of flame spread) for JP-4 (JET B) is about 30 times greater than for aviation kerosene (JET A) at the temperatures most often encountered. This is an important factor in evaluating the severity of the fire hazard encountered under these conditions and also is a factor that affects the ease of fire control under similar conditions.

This slower rate of flame propagation for JET A or kerosene grades of turbine fuel does not occur, however, where the fuel is released as a fuel mist, as frequently results in aircraft impact accidents or where the fuels are heated to or above their flash point. If a flammable or combustible liquid exists in mist form or is at a temperature above its flash point, the speed of flame spread in the mist or vapor is essentially the same, regardless of the liquid spilled.

III. Fire Control Factors.

(a) *Relative Density.*

1. The relative density of a material is commonly expressed as related to water at 60°F (16°C). All these fuels are lighter than water; the relative density of aviation gasolines is normally quoted at about 0.70, JET B turbine fuels at about 0.78, and the JET A (kerosene grade) fuels at about 0.81.

2. This means that, with respect to fire control, all of the fuels float on water. This can be a handicap during fire-fighting operations under certain conditions where sizable quantities of spilled fuel are involved.

(b) *Solubility in Water.*

1. All three of the fuels are essentially nonsoluble in water. Fires involving all three fuels

can be handled with regular foam concentrates (as opposed to alcohol types).

2. The amount of water that is entrained in the fuel due to water contamination is not particularly significant from a fire hazard viewpoint, except for the fact that the amount of water increases the static generation hazard of the fuel.

(c) *Standard Grades of Aviation Fuels.* Standard grades of aviation fuels include:

1. Aviation gasoline (AVGAS) includes all gasoline grades of fuel for reciprocating engine-powered aircraft of any octane rating. It has the general fire hazard characteristics of ordinary automotive gasoline (MOGAS).

2. JET A and JET A-1 are kerosene grades of fuel for turbine engine-powered aircraft, whatever the trade name or designation. JET A has a -40°F (-58°C) freezing point (maximum); JET A-1 incorporates special low temperature characteristics for certain operations having a -53°F (-47°C) freezing point (maximum). JP-8 (identical to JET A except for the additive package) and JP-5 (slightly less volatile than either JET A or JET A-1) are used by certain U.S. military forces. Jet A and JP-8 are known in the United Kingdom and in many former UK areas of influence as AVTUR, whereas JP-5 is similar to the UK designated AVCAT.

3. JET B is a blend of gasoline and kerosene grades of fuel for turbine engine-powered aircraft, whatever the trade name or designation. JET B is a relatively wide boiling range volatile distillate having a -60°F (-51°C) freezing point (maximum). JP-4 is one grade of JET B fuel used by the U.S. military forces; JP-4 has identical specifications to JET B as they relate to fire hazards. This fuel is known in the United Kingdom as AVTAG.

A-1-3 Listed.

The means for identifying listed equipment may vary for each organization concerned with product evaluation, some of which do not recognize equipment as listed unless it is also labeled. The authority having jurisdiction should utilize the system employed by the listing organization to identify a listed product.

A-2-1.2.5 The charge on the fuel can be reduced by the use of a static dissipater additive that increases the electrical conductivity of the fuel and thereby allows the charge to relax or dissipate more quickly, or by the use of a relaxation chamber that increases the residence time of the fuel downstream of the filter to at least 30 seconds, thereby allowing most of the charge to dissipate before the fuel arrives at the receiving tank.

API RP 2003, *Protection Against Ignitions Arising Out of Static, Lightning, and Stray Currents*, recommends a 30-second relaxation time for loading tank trucks and refuelers. However, it has not been a common practice to require a similar relaxation time for aircraft refueling, primarily because of the relatively few electrostatic incidents that have occurred during aircraft fueling.

In filling tank trucks or storage tanks, API RP 2003 recommends that at least 30 seconds of residence time be provided downstream of a filter in order to allow static charges generated in flowing fuel to relax before fuel enters the tank.

The reason it is possible to fuel aircraft safely with low conductivity fuel without providing 30 seconds relaxation time is due primarily to the difference in the geometry of aircraft tanks as compared with tank truck compartments. Flow into the aircraft normally is subdivided into several tanks simultaneously and also distributed into adjoining compartments of each tank by a multihole inlet. Bachman and Dukek[1] conducted full-scale research using a simulated large aircraft tank and concluded that none of the tanks or compartments hold sufficient fuel to allow enough charges to accumulate and create large surface voltages. Slower fill rates per compartment also allow more charge to relax.

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[1]Bachman, K.C. and Dukek, W. G., "Static Electricity in Fueling Superjets," 1972. Exxon Research & Eng. Co. Brochure, Linden, NJ.

Additionally, the inlet system of most aircraft tanks directs fuel towards the bottom of the tank to avoid splashing that generates more charge. Finally, while the hoses that connect the fueler to the aircraft provide only a few seconds of residence time for charge relaxation at high rates of flow, the actual relaxation volume in the system is significantly greater where a coated screen is used as a second stage water barrier. In this case, the vessel's volume after the first stage filter coalescer might represent an additional 15 seconds of residence time for charge relaxation. (The coated screen, unlike other water barriers, does not generate charge.)

A flammable vapor space in the tank due to the presence of Jet B or JP-4 fuels still constitutes a potential hazard. Therefore, to minimize the chance for static ignition, FAA regulations require that fueling be conducted at half of the rated flow where civil aircraft have used such fuels.

A-2-1.4.2 Radar Ignition Hazards.

(a) The beam of radar equipment has been known to cause ignition of flammable vapor-air mixtures from inductive electric heating of solid materials or from electrical arcs or sparks from chance resonant conditions. The ability of an arc to ignite flammable vapor-air mixtures depends on the total energy of the arc and the time lapse involved in the arc's duration, which is related to the dissipation characteristics of the energy involved. The intensity or peak power output of the radar unit, therefore, is a key factor in establishing safe distances between the radar antenna and fueling operations, fuel storage or fuel loading rack areas, fuel tank truck operations, or any operations where flammable liquids and vapors could be present or created.

(b) Most commercially available weather-mapping airborne radar equipment operates at peak power outputs, varying from 25 kW to 90 kW. Normally this equipment should not be operated on the ground. Tests have shown that the beam of this equipment can induce energy capable of firing flash bulbs at considerable distances. If the equipment is operated on the ground for service checking or for any other reason, the beam should not be directed toward any of the hazards described in A-2-1.4.2(a) that are located within 100 ft (30 m). (WARNING: Higher power radar equipment can require greater distances.)

(c) Airport surface detection radar operates under a peak power output of 50 kW. It is fixed rather than airborne equipment.

(d) Airborne surveillance radar of the type currently carried on military aircraft has a high peak power output. Aircraft carrying this type of radar can be readily distinguished by radomes atop or below the fuselage, or both.

(e) Aircraft warning radar installations are the most powerful. Most of these installations are, however, remotely located from the hazards specified in A-2-1.4.2(a) and therefore are not covered herein. Ground radar for approach control or traffic pattern surveillance is considered the most fire hazardous type of radar normally operating at an airport. The latter type of equipment has a peak power output of 5 MW. Where possible, new installations of this type of equipment should be located at least 500 ft (150 m) from any of the hazards described in A-2-1.4.2(a).

A-2-1.6.1 Multipurpose dry chemical (ammonium phosphate) should not be selected due to corrosion concerns relative to the agent. Carbon dioxide extinguishers should not be selected due to their limited range and effectiveness in windy conditions.

A-2-1.7

Deadman controls should be designed so that the operator can use them comfortably while wearing gloves and hold them for the time needed to complete the operation. A pistol grip deadman device that is squeezed to operate is preferable to a small button that needs to be held by a thumb or finger.

A-2-2

The section on aircraft refueling hose has been altered extensively by referencing API BULL 1529, *Aviation Fueling Hose*. NFPA 407 formerly contained many requirements for hose, but it was intended only to address features that might be related to a fire or the results of a fire. It was not until 1982 that a comprehensive aircraft refueling hose specification was published by API. Prior to that time, NFPA 407 was the only document in existence that addressed this subject.

API BULL 1529 deals with all aspects of hose safety, including the couplings that are acceptable.

NFPA 407 recognizes the need for an extensive document such as API BULL 1529 and requires hoses that meet that standard. However, it is important to recognize that API does no testing and it does not regulate those manufacturers who claim to sell hose that meets API BULL 1529. The hose user and the cognizant authority in charge might find it prudent to require hose manufacturers to produce copies of test reports or documents that certify that hoses using the identical construction and compounds have been tested and have passed all requirements of API BULL 1529 satisfactorily.

A-2-3.6.3 Electrical Equipment in Aircraft Fuel Servicing Vehicle Engine Compartments. Equipment contained in the engine compartment or vehicle cab and located 18 in. (457 mm) or more aboveground may be permitted to be of the general purpose type.

A-2-3.20.4 Optional Precautions Against Misfueling of Aircraft Fuel Servicing Tank Vehicles. The coupler and truck fitting should be equipped with coded lugs or a mechanical device to ensure product selection and to prevent mixing of products. This might not be feasible on over-the-road-type tank vehicles.

A-2-4.4.1 Optional Guidance on Fuel Storage Tanks. Where pressure tanks are used, details on construction, spacing, and location should be in accordance with industry good practice and approved by the authority having jurisdiction. When AVGAS, MOGAS, or JET B turbine fuels are stored in bulk quantities in aboveground tanks, they should be stored in floating roof-type tanks. Covered floating roof tanks minimize the hazardous flammable vapor-air space above the liquid level. The vapor spaces of underground tanks storing fuels should not be interconnected.

A-2-4.5.2 Discussion of Fuel Transfer Methods. Fuel transfer by pumping is the more common procedure and normally is preferred from a fire protection standpoint, since it allows rapid shutdown of fuel flow through pump shutdown. Gravity transfer is the simplest method but normally is limited to relatively low flow rates. Because the static head does exert some pressure in the system, a safety shutdown should include a valve or valves located as close to the tank as practicable.

A-2-4.5.4 Alarms for Emergency Shutoff System. The operation of the emergency shutoff control should sound an alarm at the airport fire crew station and at the fuel storage facility.

A-2-4.6.11 System Component Isolation Guidance. Flanged connections should be provided for ease of dismantling and to avoid cutting and welding after the system has been placed in service. The location of these isolation devices depends upon the size and character of each system, but the following locations generally apply (*see Figure A-2-4.6.11*):

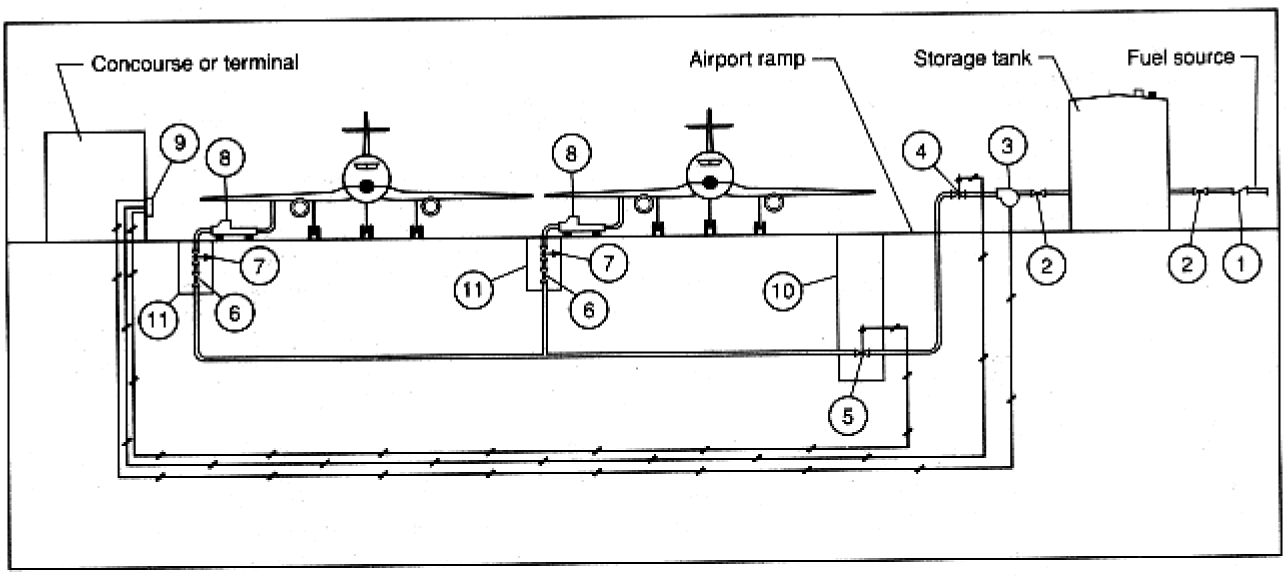
(a) At each storage tank;

(b) At each pump;

(c) At each filter separator;

(d) At each hydrant or on each hydrant lateral;

(e) At each flow regulator or pressure control valve.



NOTE: No dimensional relationship exists between elements in this figure. Refer to this standard, NFPA 30, *Flammable and Combustible Liquids Code*, NFPA 70, *National Electrical Code*, and FAA Regulations for separations and clearances.

1. Check valve at tank inlet
2. Isolation valve at tank inlet/outlet
3. Pumping system
4. Pump discharge control valve or hydrant system shutoff valve (alternate location)
5. Hydrant system shutoff valve (alternate location)
6. Hydrant shutoff valve
7. Hydrant pit valve
8. Hydrant fueling servicing vehicle
9. Emergency fuel shutoff station
10. Valve box
11. Hydrant pit

Figure A-2-4.6.11 Typical fixed airport fueling system isolation valving — operating and emergency controls.

A-2-4.7.3 Location of Surge Suppressors. Where surge suppressors are necessary, they should be located so that exposure to vehicular traffic, weather conditions, and the result of accidental rupture is minimized.

A-2-4.12

Cathodic protection is recommended for metal components of airport fueling systems and fuel storage facilities that are in contact with the ground. There are two types of cathodic protection as follows:

(a) The galvanic anode method, which generates its own current;

(b) The impressed current method, which has an external current source.

A-2-6.3.5 Although it is not technologically possible to have a bonding system that is 100 percent fail-safe, there are devices available that can help ensure that a proper bond has been established before fueling.

A-3-2 Handling Fuel Spills.

The following actions are appropriate in the event of a fuel spill, although each spill should be treated as an individual case due to such variables as the size of the spill, type of flammable or combustible liquid involved, wind and weather conditions, equipment arrangement, aircraft occupancy, emergency equipment, and personnel available.

(a) The flow of fuel should be stopped, if possible. If the fuel is discovered leaking or spilling from fuel servicing equipment or hoses, the emergency fuel shutoff should be operated at once. If the fuel is discovered leaking or spilling from the aircraft at the filler opening, vent line, or tank seams during fueling operations, fueling should be stopped immediately. Evacuation of the aircraft should be ordered when necessary. The aircraft then should be thoroughly checked for damage or entrance of flammable liquid or vapors into any concealed wing or fuselage area, and corrective action should be taken as necessary before it is returned to normal operational service.

(b) The airport fire crew should be notified if the spill presents a fire hazard. The only routine exceptions are for small spills. Supervisory personnel should be notified to ensure that operations in progress can be continued safely or halted until the emergency is past and that corrective measures can be taken to prevent recurrence of a similar accident.

(c) It might be necessary to evacuate the aircraft if the spill poses a serious fire exposure to the aircraft or its occupants. Walking through the liquid area of the fuel spill should not be permitted. Persons who have been sprayed with fuel or had their clothing soaked with fuel should go to a place of refuge, remove their clothing, and wash. Individuals whose clothing has been ignited should be wrapped in blankets, coats, or other items or should be told to or forced to roll on the ground.

(d) Mobile fueling equipment and all other mobile equipment should be withdrawn from the area or left as is until the spilled fuel is removed or made safe. No fixed rule can be made, as fire safety varies with circumstances. Shutting down equipment or moving vehicles can provide a source of ignition if no fire immediately results from the spillage.

(e) Aircraft, automotive, or spark-producing equipment in the area should not be started before the spilled fuel is removed or made safe. If a vehicle engine is running at the time of the spill, it normally is good practice to drive the vehicle away from the hazard area unless the hazard to personnel is judged too severe. Fuel servicing vehicles in operation at the time of the spill should not be moved until a check is made to verify that any fuel hose that might have been in use or connected between the vehicle and the aircraft is safely stowed.

(f) If any aircraft engine is operating at the time of the spill, it normally is good practice to move the aircraft away from the hazard area unless air currents set up by operating power plants would aggravate the extent or the nature of the existing vapor hazard.

(g) If circumstances dictate that operating internal combustion engine equipment within a spill area that has not ignited should be shut down, engine speeds should be reduced to idle prior to cutting ignition in order to prevent backfire.

(h) The volatility of the fuel can be a major factor in the initial severity of the hazard created by a spill. Gasoline and other low flash point fuels at normal temperatures and pressures produce vapors that are capable of forming ignitible mixtures with the air near the surface of the liquid, whereas this condition does not normally exist with kerosene fuels (JET A or JET A-1) except where ambient temperatures are 100°F (38°C) or above or where the liquid has been heated to a similar temperature.

(i) Spills of gasoline and low flash point turbine fuels (JET B) greater than 10 ft (3 m) in any dimension and covering an area of over 50 ft^2 (5 m^2) or that are of an ongoing nature should be blanketed or covered with foam. The nature of the ground surface and the existing exposure conditions dictate the exact method to be followed. Such fuels should not be washed down sewers or drains. The decision to use a sewer or drain should be made only by the chief of the airport fire brigade or the fire department. If fuels do enter sewers, either intentionally or unintentionally, large volumes of water should be introduced to flush such sewers or drains as quickly as possible to dilute the flammable liquid content of the sewer or drain to the maximum possible extent. Normal operations involving ignition sources (including aircraft and vehicle operations) should be prohibited on surface areas adjacent to open drains or manholes from which flammable vapors might issue due to the introduction of liquids into the sewer system until it can be established that no flammable vapor-air mixture is present in the proximity.

NOTE: See NFPA 415, *Standard on Aircraft Fueling Ramp Drainage*, for further information on aircraft fueling ramp drainage designs to control the flow of fuel that might be spilled on a ramp and to minimize the resulting possible danger.

(j) Spills of kerosene grades of aviation fuels (JET A or JET A-1) greater than 10 ft (3 m) in any dimension and covering an area of over 50 ft^2 (5 m^2) or that are of an ongoing nature and that have not ignited should be blanketed or covered with foam if there is danger of ignition. If there is no danger of ignition, an absorbent compound or an emulsion-type cleaner can be used to clean the area. Kerosene does not evaporate readily at normal temperatures and should be cleaned up. Smaller spills can be cleaned up using an approved, mineral-type, oil absorbent.

(k) Aircraft on which fuel has been spilled should be inspected thoroughly to ensure that no fuel or fuel vapors have accumulated in flap well areas or internal wing sections not designed for fuel tankage. Any cargo, baggage, express, mail sacks, or similar items that have been wetted by fuel should be decontaminated before being placed aboard any aircraft.

A-3-4 Bonding.

Hydrocarbon fuels, such as aviation gasoline and JET A, generate electrostatic charge when passing through the pumps, filters, and piping of a fuel transfer system. (The primary electrostatic generator is the filter/separator that increases the level of charge on a fuel by a factor of 100 or more as compared with pipe flow.) Splashing, spraying, or free-falling of the fuel further enhances the charge. When charged fuel arrives at the receiving tank (cargo tank or aircraft fuel tank) one of two possible events will occur:

(a) The charge will relax harmlessly to ground; or

(b) If the charge or the fuel is sufficiently high, a spark discharge can occur. Whether or not an ignition follows depends on the energy (and duration) of the discharge and the composition of the fuel/air mixture in the vapor space (i.e., whether or not it is in the flammable range).

The amount of charge on a fuel when it arrives at the receiving tank, and hence its tendency to cause a spark discharge, depends on the nature and amount of impurities in the fuel, its electrical conductivity, the nature of the filter media (if present), and the relaxation time of the system [i.e., the residence time of the fuel in the system between the filter (separator) and the receiving tank]. The time needed for this charge to dissipate is dependent upon the conductivity of the fuels; it could be a fraction of a second or several minutes.

No amount of bonding or grounding prevents discharges from occurring inside of a fuel tank. Bonding ensures that the fueling equipment and the receiving tank (aircraft or fueler) are at the same potential and provides a path for the charges separated in the fuel transfer system (primarily the filter/separator) to combine with and neutralize the charges in the fuel. Also, in overwing fueling and in top loading of cargo tanks, bonding ensures that the fuel nozzle or the fill pipe is at the same potential as the receiving tank, so that a spark does not occur when the nozzle or fill pipe is inserted into the tank opening. For this reason, the bonding wire must be connected before the tank is opened.

Grounding during aircraft fueling or refueler loading is no longer required because:

(a) It does not prevent sparking at the fuel surface (*see NFPA 77, Recommended Practice on Static Electricity*).

(b) It is not required by NFPA 77, *Recommended Practice on Static Electricity*.

(c) The static wire might not be able to conduct the current in the event of an electrical fault in the ground support equipment connected to the aircraft and could constitute an ignition source if the wire fuses. If ground support equipment is connected to the aircraft or if other operations are being conducted that necessitate electrical earthing, then separate connections should be made for this purpose. Static electrical grounding points can have high resistance and, therefore, are unsuitable for grounding.

For a more complete discussion of static electricity in fuels, see NFPA 77, *Recommended Practice on Static Electricity*.

A-3-4.3

Ordinary plastic funnels or other nonconducting materials can increase static generation. The use of chamois as a filter is extremely hazardous.

A-3-7 Electric Hand Lamps.

Electric hand lamps used in the immediate proximity of the fueling operation should be of the type approved for use in NFPA 70, *National Electrical Code*, Class I, Division 1, Group D hazardous locations. There is no supportable basis for requiring in the petroleum industry the use of approved, listed, or permitted two- or three-cell flashlights to avoid igniting Class I, Group D vapors.

A-3-7.2 Aircraft Ground-Power Generators.

Aircraft ground-power generators should be located as far as practical from aircraft fueling points and tank vents to reduce the danger of igniting flammable vapors that could be discharged during fueling operations at sparking contacts or on hot surfaces of the generators.

A-3-9

It is impossible to establish precise rules for fueling when there are electrical storms in the vicinity of the airport. The distance of the storm from the airport, the direction in which it is traveling, and its intensity are all factors to be weighed in making the decision to suspend fueling operations temporarily. Experience and good judgment are the best guides. Sound travels approximately $^{1}/_{5}$ mi/sec (322 m/sec). The approximate number of miles to the storm can be determined by counting the seconds between a flash of lightning and the sound of thunder and dividing by 5.

A-3-10.2 Aircraft Fuel Servicing Locations.

The precautions in 3-10.2 are intended to minimize the danger of the ignition of any flammable vapors discharged during fueling and of fuel spills by sources of ignition likely to be present in airport terminal buildings.

A-3-13 Portable Fire Extinguishers on Aircraft Servicing Ramps or Aprons.

Fire extinguishers for ramps where fueling operations are conducted are intended to provide an immediate means of fire protection in an area likely to contain a high concentration of personnel and valuable equipment. The prominent and strategic positioning of portable fire extinguishers is essential in order for them to be of a maximum value in the event of an emergency. Extinguishers should not be located in probable spill areas. For normal, single parking configurations, extinguishers specified for protection of fuel servicing operations should be located along the fence, at terminal building egress points, or at emergency remote control stations of airport fixed-fuel systems. To provide accessibility from adjoining gates, particularly where more than one unit is specified, extinguishers may be permitted to be located approximately midway between gate positions. Where this is done, the maximum distance between extinguishers should not be over 300 ft (90 m). Where the specified extinguishers are not located along the fence but are brought into the servicing area prior to the fueling operation, they should be located upwind not over 100 ft (30 m) from the aircraft being serviced. For protection of fuel servicing of aircraft that are double parked or triple parked, extinguishers should be located upwind not over 100 ft (30 m) from the aircraft being serviced.

A-3-13.5 Protection of Extinguishers Against Inclement Weather.

During inclement weather, extinguishers not in enclosed compartments may be permitted to be protected by canvas or plastic covers. If icing occurs, the extinguisher should be sprayed with deicing fluid.

A-3-13.6 Training of Personnel in the Utilization of Extinguishers.

Fuel servicing personnel should be given adequate training with extinguishers so that such equipment is used effectively in an emergency. Such training should be given on fires of the type that could be encountered on the job. To ensure prompt action in the event of a spill or other hazardous condition developing during fueling operations, aircraft servicing personnel also should be trained in the operation of emergency fuel shutoff controls. Each new fuel servicing employee should be given indoctrination training covering these and similar safety essentials that are related to the job. Follow-up and advanced training should be given as soon as the employee is sufficiently acquainted with the work to benefit from such training. Supervisors should be given training in the more technical aspects of fire safety so that they understand the reason for these and similar requirements and have an appreciation for the responsibility of a supervisor or the safety of an operation.

A-3-16

Failure of aircraft fueling hose in service is a potential source of fuel spillage and a potential fire hazard. The principal reasons for failure of aircraft fueling hoses include:

(a) Using damaged hoses.

(b) Using aged hoses.

(c) Exceeding pressure limits.

(d) Improper installation.

A-3-21.2

(b) If passengers remain onboard an aircraft during fuel servicing, at least one person trained in emergency evacuation procedures is required to be aboard (*see 3-11.1*). It is not intended that the pilot in command perform this function.

Appendix B Referenced Publications

B-1

The following documents or portions thereof are referenced within this standard for informational purposes only and thus are not considered part of the requirements of this document. The edition indicated for each reference is the current edition as of the date of the NFPA issuance of this document.

B-1.1 NFPA Publications.

National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.

NFPA 30, *Flammable and Combustible Liquids Code*, 1993 edition.

NFPA 70, *National Electrical Code*, 1996 edition.

NFPA 77, *Recommended Practice on Static Electricity*, 1993 edition.

NFPA 415, *Standard on Aircraft Fueling Ramp Drainage*, 1992 edition.

B-1.2 Other Publications.

B-1.2.1 API Publications. American Petroleum Institute, 2101 L Street NW, Washington, DC 20037.

API BULL 1529, *Aviation Fueling Hose*, 1989.

API RP 2003, *Protection Against Ignitions Arising Out of Static, Lightning, and Stray Currents*, 1991.

B-1.2.2 ASTM Publications. American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103.

ASTM D 86, *Standard Test Method for Distillation of Petroleum Products*, 1995.

ASTM D 323, *Standard Test Method for Vapor Pressure of Petroleum Products (Reid Method)*, 1994.

B-1.2.3 *An Evaluation of the Relative Fire Hazards of JET A and JET B for Commercial Flight* (N74-10709), National Technical Information Service, U.S. Dept. of Commerce, Springfield, VA 22151.

B-2 Bibliography.

B-2.1 API Publication.

American Petroleum Institute, 2101 L Street NW, Washington, DC 20037.

API STD 2000, *Venting Atmospheric and Low-Pressure Storage Tanks*, 1992.

B-2.2 ASTM Publications.

American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103.

ASTM D 910, *Standard Specification for Aviation Gasolines*, 1995.

ASTM D 1655, *Standard Specification for Aviation Turbine Fuels*, 1995.

NFPA 408

1994 Edition

Standard for Aircraft Hand Portable Fire Extinguishers

1994 Edition

This edition of NFPA 408, *Standard for Aircraft Hand Portable Fire Extinguishers*, was prepared by the Technical Committee on Aircraft Rescue and Fire Fighting and acted on by the National Fire Protection Association, Inc., at its Annual Meeting held May 16-18, 1994, in San Francisco, CA. It was issued by the Standards Council on July 14, 1994, with an effective date of August 5, 1994, and supersedes all previous editions.

The 1994 edition of this document has been approved by the American National Standards

Institute.

Origin and Development of NFPA 408

Work on this standard started in 1947 after requests were received by the National Fire Protection Association for recommendations on aircraft hand fire extinguishers. During the intervening years, prior to the adoption of the first draft of this text in 1955 by the Association, a number of proposals were prepared and circulated for comment and criticism. In 1956 a revision was adopted incorporating an appendix on air crew training. Revisions were made in 1964, 1965, 1970, and 1973.

The 1984 document was completely revised to recognize state-of-the-art developments in extinguishing agents and to bring the document into form with the NFPA *Manual of Style*.

The 1989 edition was a reconfirmation of the 1984 edition. This edition is a complete revision and was developed by a task group made up of the following individuals:

Task Group on Aircraft Hand Fire Extinguishers

John J. O'Sullivan, British Airways, Heathrow Airport (London), England, Chair; Paul E. Calderwood, Everett Fire Dept., MA; Paul O. Huston, Amerex Corp., AL; Gaetan Perron, Dept. of Nat'l Defence, Ottawa, ON, Canada; Bertrand F. Ruggles, US FAA Dept. of Transportation, Washington, DC; John M. Schuster, 3M Co., MN; John X. Stefanki, John X. Stefanki Inc., CA; Mark T. Conroy, NFPA Staff Liaison.

Technical Committee on Aircraft Rescue and Fire Fighting

John F. Rooney, *Chair*
Tucson, AZ

James F. O'Regan, *Vice Chair*
Westboro, MA

Robert J. Donahue, *Secretary*
Massport, MA

Brian Boucher, Canadian Air Line Pilots Assn., Canada
Rep. Canadian Air Line Pilots Assn.

Booker T. Burley, Hartsfield Atlanta Int'l Airport, GA

Ralph Colet, John Russo Industrial Inc.

Robert L. Darwin, U.S. Dept. of the Navy, DC

Charlie L. Duncan, Atlanta Fire Dept., GA

B. V. Hewes, Airport Safety Services, GA

Paul O. Huston, Amerex Corp., AL
Rep. Fire Equipment Mfrs. Assn., Inc.

D. Steve Kiernan, Chubb Nat'l Foam Inc., PA

L. M. Krasner, Factory Mutual Research Corp., MA

Dave Lenz, Oshkosh Truck Corp., WI

Thomas J. Lett, Albuquerque Fire & Safety Assoc., Inc., NM
Rep. NFPA Fire Service Section

D. Robin Maryon, Simon Gloster Saro Ltd., England

John J. O'Sullivan, British Airways, England

Davis R. Parsons, Los Angeles City Fire Dept., CA

Gaetan Perron, Dept. of Nat'l. Defence, Canada

Robert G. Relyea, ARFF Working Group, TX

Robert E. Reyff, U.S. Air Force, FL

Paul R. Robinson, Kennesaw, GA
Rep. Air Line Pilots Assn.

Bertrand F. Ruggles, U.S. FAA Dept. of Transportation, DC

Joseph L. Scheffey, Hughes Assoc., Inc., MD

John M. Schuster, 3M Co., MN

John X. Stefanki, John X. Stefanki Inc., CA

William J. Wenzel, Schenectady, NY
Rep. Walter Truck Corp.

Ronald O. Wikander, Lockheed Aeronautical Systems Co., GA

Larry E. Williams, Emergency Response Training Academy, Inc., TN

Joseph A. Wright, Federal Aviation Administration Tech Ctr., NJ

Alternates

Fred B. Goodnight, Amerex Corp., AL
(Alt. to P. O. Huston)

Frank M. E. Hughes, British Airways, England
(Alt. to J. J. O'Sullivan)

Robert E. Maxwell, Dept. of Nat'l Defence, Canada
(Alt. to G. Perron)

Thomas E. McMaster, Los Angeles City Fire Dept., CA
(Alt. to D. R. Parsons)

William E. Moore, U.S. Federal Aviation Admin., CO
(Alt. to B. F. Ruggles)

Daniel A. Nomensen, Emergency One, Inc., FL
(Alt. to Emergency One, Inc.)

Richard E. Ottman, 3M Co., MN
(Alt. to J. M. Schuster)

William S. Weeks, Air Line Pilots Assn., NC
(Alt. to P. R. Robinson)

Nonvoting

John Cedric Black, BAA plc, England

Derek K. G. Dodwell, Civil Aviation Authority, England

Gary Hammack, Nat'l Transportation Safety Board (TE-10), DC
(Alt. to L. D. Roman)

John E. Lodge, Lodge Fire Protection Consultancy Ltd., England

Lawrence D. Roman, U.S. Nat'l Transportation Safety Board, DC

David F. Short, Carmichael Int'l Ltd, England

Mark T. Conroy, NFPA Staff Liaison

This list represents the membership at the time the Committee was balloted on the text of this edition. Since that time, changes in the membership may have occurred.

NOTE: Membership on a Committee shall not in and of itself constitute an endorsement of the Association or any document developed by the Committee on which the member serves.

Committee Scope: This Committee shall have primary responsibility for documents on aircraft rescue and fire-fighting services and equipment, procedures for handling aircraft fire emergencies, and for specialized vehicles used to perform these functions at airports, with particular emphasis on saving lives and reducing injuries coincident with aircraft fires following impact or aircraft ground fires. The Committee shall develop aircraft fire investigation procedures as an aid to accident prevention and the saving of lives in future aircraft accidents involving fire.

NFPA 408
Standard for
Aircraft Hand Portable Fire Extinguishers

1994 Edition

NOTICE: An asterisk (*) following the number or letter designating a paragraph indicates explanatory material on that paragraph in Appendix A.

Information on referenced publications can be found in Chapter 6 and Appendix B.

Chapter 1 Administration

1-1 Scope.

1-1.1

This standard specifies requirements for the type, capacity, rating, number, location, installation, and maintenance of aircraft hand portable fire extinguishers to be provided for the use of flight crew members or other occupants of an aircraft for the control of incipient fires in the areas of aircraft that are accessible during flight.

1-1.2

This standard also includes requirements for training flight crew members in the use of these extinguishers.

1-1.3

This standard does not cover fire detection and fixed fire extinguishing systems installed in an aircraft, or fire detection and fire extinguishing systems for the protection of ground maintenance operations.

1-1.4

Specific protection for Class D fires, and fires in hazardous materials, is beyond the scope of this standard.

1-2 Purpose.

1-2.1

This standard is intended for use by those responsible for selecting, purchasing, installing, approving, and maintaining aircraft hand portable fire extinguishers and for those responsible for training personnel in their use.

1-2.2*

The specific requirements established in this standard are intended for the particular environment of an aircraft where fire extinguishment must be the first priority.

1-2.3*

Hand portable fire extinguishers, as specified in NFPA 10, *Standard for Portable Fire Extinguishers*, have the general purpose of serving as first aid fire-fighting appliances. Accordingly, the requirements of Chapters 4 and 5 of NFPA 10, *Standard for Portable Fire Extinguishers*, are applicable to the aviation environment, and are supplemental to the specific requirements of this standard.

1-3* Definitions.

Aircraft Hand Portable Fire Extinguisher. An approved, portable device carried and operated by hand containing an extinguishing agent that can be expelled under pressure for the purpose of suppressing or extinguishing fire.

Approved. Acceptable to the authority having jurisdiction.

NOTE: The National Fire Protection Association does not approve, inspect, or certify any installations, procedures, equipment, or materials; nor does it approve or evaluate testing laboratories. In determining the acceptability of installations, procedures, equipment, or materials, the authority having jurisdiction may base acceptance on compliance with NFPA or other appropriate standards. In the absence of such standards, said authority may require evidence of proper installation, procedure, or use. The authority having jurisdiction may also refer to the listings or labeling practices of an organization concerned with product evaluations that is in a position to determine compliance with appropriate standards for the current production of listed items.

Authority Having Jurisdiction. The organization, office, or individual responsible for approving equipment, an installation, or a procedure.

NOTE: The phrase “authority having jurisdiction” is used in NFPA documents in a broad manner, since jurisdictions and approval agencies vary, as do their responsibilities. Where public safety is primary, the authority having jurisdiction may be a federal, state, local, or other regional department or individual such as a fire chief; fire marshal; chief of a fire prevention bureau, labor department, or health department; building official; electrical inspector; or others having statutory authority. For insurance purposes, an insurance inspection department, rating bureau, or other insurance company representative may be the authority having jurisdiction. In many circumstances, the property owner or his or her designated agent assumes the role of the authority having jurisdiction; at government installations, the commanding officer or departmental official may be the authority having jurisdiction.

Bar. See Galley.

Buffet. See Galley.

Cargo Aircraft. An aircraft that is configured solely to carry cargo and no personnel other than the flight crew and any additional crew required for the care of the cargo.

Cargo/Baggage Compartment. An enclosed compartment within, or attached to, an aircraft fuselage and separate from the passenger and flight crew areas. It almost always is accessible only from the exterior of the fuselage.

Class A Fire. A fire that involves ordinary solid combustible materials such as wood, cloth, paper, rubber, and many plastics.

Class B Fire.* A fire that involves a flammable or combustible liquid such as oil, fat, alcohol, gasoline, and hydraulic fluid. Some plastics behave like Class A combustibles up to a point, but then they develop many attributes of a Class B fire.

Class C Fire.* A fire that involves energized electrical equipment or wiring.

Class D Fire.* A fire that involves combustible metals such as magnesium, titanium, zirconium, sodium, lithium, and potassium.

Cockpit. See Flight Deck.

COMBI. An aircraft designed to transport both passengers and cargo on the same level within the fuselage.

Extinguisher(s). See Aircraft Hand Portable Fire Extinguisher.

Flight Crew. Those members of the aircraft crew whose responsibilities include the operation and management of the aircraft flight controls, engine(s), and systems, i.e., pilot in command (captain), first officer (co-pilot), second officer (flight engineer), etc.

Flight Deck. The area of an aircraft arranged for use of the flight crew in operating the aircraft. Berths, galleys, and lavatory facilities may be associated with the flight crew compartment but are not included in the term "flight deck."

Galley. An area of an aircraft used for storing, refrigerating, heating, and dispensing food and beverages. Such areas typically include areas for storing plastic trays, plastic dinnerware utensils, and paper napkins.

Halogenated Agents. Halogenated agents referenced in this standard are bromotrifluoromethane (Halon 1301), bromochlorodifluoromethane (Halon 1301), and mixtures of Halon 1211 and Halon 1301 (Halon 1211/1301). Approved, listed, and labeled extinguishers containing clean evaporating type HCFC or HFC halogenated replacement agents also shall be permitted to be used to comply with the requirements of this standard.

NOTE: Halon 1211 and Halon 1301 are included in the "Montreal Protocol on Substances that Deplete the Ozone Layer" signed September 16, 1987. The 1992 amendments to the protocol call for a cessation of production of Halon 1211 and Halon 1301 worldwide.

Halon 1211. The chemical name is bromochlorodifluoromethane, $CBrClF_2$. Halon 1211 is a multipurpose, Class ABC-rated agent effective against flammable liquid fires. Due to its relatively high boiling point (+25°F/-4°C), Halon 1211 discharges as an 85 percent liquid stream offering long agent throw range.

Halon 1301. The chemical name is bromotrifluoromethane, $CBrF_3$. Halon 1301 is recognized as an agent having Class ABC capability in total flooding systems; however, Halon 1301 offers limited Class A capability when used in hand portable fire extinguishers.

Hand Fire Extinguisher(s). See Aircraft Hand Portable Fire Extinguisher.

Labeled. Equipment or materials to which has been attached a label, symbol, or other identifying mark of an organization that is acceptable to the authority having jurisdiction and concerned with product evaluation that maintains periodic inspection of production of labeled equipment or materials and by whose labeling the manufacturer indicates compliance with appropriate standards or performance in a specified manner.

Listed. Equipment or materials included in a list published by an organization acceptable to the authority having jurisdiction and concerned with product evaluation that maintains periodic inspection of production of listed equipment or materials and whose listing states either that the equipment or material meets appropriate standards or has been tested and found suitable for use in a specified manner.

NOTE: The means for identifying listed equipment may vary for each organization concerned with product evaluation, some of which do not recognize equipment as listed unless it is also labeled. The authority having jurisdiction should utilize the system employed by the listing organization to identify a listed product.

Maximum Certificated Occupant Capacity. The maximum number of persons that can be carried as certified for each specific aircraft model by the authority having jurisdiction. (In the United States the authority having jurisdiction is the Federal Aviation Administration.)

May. This term is used to state a permissive use or an alternative method to a specified requirement.

Passenger Aircraft. An aircraft designed for the primary function of carrying passengers.

Rated/Rating. A numerical value assigned to an extinguisher based upon its fire extinguishing capability in accordance with ANSI/UL 711, *Standard for Rating and Fire Testing of Fire Extinguishers*.

Shall. Indicates a mandatory requirement.

Should. Indicates a recommendation or that which is advised but not required.

Chapter 2 Types and Capacities

2-1 General.

2-1.1

Hand portable fire extinguishers should meet or exceed all of the requirements of one of the fire test standards and one of the appropriate performance standards listed below.

2-1.1.1 Extinguishers installed in the United States shall meet the requirements of the following ANSI standards:

(a) Fire Test Standard: ANSI/UL 711

(b) Performance Standards

1. Dry Chemical Types: ANSI/UL 299
2. Water Types: ANSI/UL 626
3. Halon Types: ANSI/UL 1093
4. Film Forming Types: ANSI/UL 8

2-1.1.2 Extinguishers installed in Canada shall meet the requirements of the following Canadian standards:

(a) Fire Test Standard: CAN/ULC S508-M90

(b) Performance Standards

1. Dry Chemical Types: CAN/ULC-S504-M88

2. Water Types: CAN4-S507-M83

3. Halon Types: CAN/ULC-S512-M87

2-1.2

Identification of the listing and labeling organization, with ratings and classifications, including the performance standard that the extinguisher meets or exceeds, shall be clearly marked on each extinguisher.

2-1.2.1 An organization listing, labeling, and marking extinguishers used to comply with the requirements of this standard shall utilize a third-party certification program for hand portable fire extinguishers that meets or exceeds the requirements of ANSI/UL 1803, *Standard for Factory Follow-Up on Third Party Certified Portable Fire Extinguishers.*

Exception No. 1: Extinguishers manufactured prior to January 1, 1989.

Exception No. 2: Certification organizations accredited by the Standards Council of Canada.

2-1.3*

All aircraft hand fire extinguishers shall function properly at temperature ranges from -40°F to 120°F (-40°C to 49°C).

2-1.4*

Water extinguishers having a capacity of $1^{3}/_{8}$ qt (2 L), and having special approval of the authority having jurisdiction, shall not be required to be labeled, and shall comply with 2-1.1, 2-1.2, and 2-1.3 of this chapter.

2-2 Water.

2-2.1

Water-based extinguishers shall have a minimum 1-A rating and shall be equipped with either a spray or straight stream nozzle.

2-2.2

Water-based extinguishers shall not be used on Class B or Class C or Class D fires.

2-2.3

Cargo compartments shall have a water-based extinguisher(s) with a minimum rating of 2-A.

2-3 Halogenated Agents.

2-3.1*

Only halogenated agents specified in this standard shall be used in hand fire extinguishers in aircraft.

2-3.2

Halon 1211 purchased for recharging extinguishers shall meet the requirements of Military Specification MIL-B-38741.

2-3.3

Halon 1301 purchased for recharging extinguishers shall meet the requirements of Military Specification MIL-M-12218C.

2-3.4* Halon 1211 Extinguishers.

2-3.4.1* For occupied spaces on aircraft, Halon 1211 extinguishers shall not be less than $2^1/_2$ lb (1.2 kg) capacity, and shall not be more than 5 lb (2.3 kg) capacity. These extinguishers shall have a minimum 5-B:C rating, not less than 8-sec effective discharge time, not less than a 10-ft (3-m) liquid range, and may be equipped with a discharge hose.

2-3.4.1.1* For occupied spaces on small aircraft only, with a maximum certificated occupant capacity of one to four persons including the pilot, a Halon 1211 extinguisher with a minimum 2-B:C rating shall be permitted to be used as an option to the Halon 1301 extinguishers specified in Table 3-1.1.

2-3.4.2 For accessible cargo compartments of COMBI aircraft and cargo aircraft, Halon 1211 extinguishers shall not be less than 13 lb (5.9 kg) capacity, and shall have a minimum 2-A: 40-B:C rating.

2-3.4.3 The total Halon 1211 agent available in all extinguishers in any single compartment, if discharged simultaneously, shall not be capable of producing a concentration greater than 2 percent by volume at 120°F (49°C) in the compartment.

2-4 Carbon Dioxide.

2-4.1

For occupied spaces on aircraft, carbon dioxide (CO_2) extinguishers shall not be used.

2-4.2

For cargo compartments of COMBI aircraft and cargo aircraft, CO_2 extinguishers shall not be used.

2-5 Dry Chemical.

2-5.1*

For occupied spaces on aircraft, dry chemical extinguishers shall not be used.

2-5.2

For cargo compartments of COMBI aircraft and cargo aircraft, dry chemical extinguishers shall not be less than 10-lb (4.5-kg) capacity, and shall have a minimum 2-A: 40-B:C rating.

2-6 Dry Powder.

2-6.1*

For occupied spaces on aircraft, dry powder extinguishers for Class D fires shall not be used.

2-6.2

For accessible cargo compartments of COMBI aircraft and cargo aircraft, dry powder extinguishers for Class D fires may be provided in addition to required extinguishers specified in 3-2.2 of this standard.

2-7 Other Agents.

2-7.1

Hand portable fire extinguishers carrying non- halogenated-type agents developed to replace halon shall be listed and labeled.

Chapter 3 Distribution of Extinguishers

3-1 Passenger Aircraft.

3-1.1

Aircraft hand portable fire extinguishers shall be placed in occupied spaces on aircraft as specified in Table 3-1.1.

Table 3-1.1 Distribution of Extinguishers in Occupied Spaces on Aircraft

Maximum Certificated Occupant Capacity	Number of Extinguishers	Type of Extinguisher	Location
1-4 (including pilot)	1	Halon 1301	Within Reach of Seated Pilot
		Halon 1211 optional	
		(See 2-3.4.1.1, 2-3.4.3, 2-3.4.3)	
5-30	1	Halon 1301 or Halon 1211	Within Reach of Seated Pilot
	1	Halon 1211	Cabin
31-60	1	Halon 1301 or Halon 1211	Flight Deck
	2	One water and one Halon 1211	Cabin
	1	Halon 1211	Each Galley (See 3-1.2)
61-120	1	Halon 1301 or Halon 1211	Flight Deck
	3	One water and two Halon 1211	Cabin
	1	Halon 1211	Each Galley (See 3-1.2)
121-200	1	Halon 1301 or Halon 1211	Flight Deck
	4	Two water and two Halon 1211	Cabin
	1	Halon 1211	Each Galley (See 3-1.2)
201-275	1	Halon 1301 or Halon 1211	Flight Deck
	5	Two water and three Halon 1211	Cabin

	1	Halon 1211	Each Galley (See 3-1.2)
276-400	1	Halon 1301 or Halon 1211	Flight Deck
	8	Four water and four Halon 1211	Cabin
	1	Halon 1211	Each Galley (See 3-1.2)
Greater than 400	1	Halon 1301 or Halon 1211	Flight Deck
	10	Five water and five Halon 1211	Cabin
	1	Halon 1211	Each Galley (See 3-1.2)
COMBI Aircraft	1	Halon 1301 or Halon 1211	Flight Deck
Wide-body	5	Two water and three Halon 1211	Cabin
	1	Halon 1211	Each Galley (See 3-1.2)
	4	Halon 1211	Cargo (PAX level)
	2	Water	
COMBI Aircraft	1	Halon 1301 or Halon 1211	Flight Deck
Narrow-body	4	Two water and two Halon 1211	Cabin
	1	Halon 1211	Each Galley (See 3-1.2)
	2	Halon 1211	Cargo (PAX level)
	2	Water	

3-1.2

Where an extinguisher, other than a water extinguisher, is located within 5 ft (1.5 m) of a galley opening and on the same floor level, an additional extinguisher shall not be required for the galley.

3-1.3

Where distances between extinguishers, as measured by normal aisle travel, exceed 60 ft (18 m), extinguishers in addition to those required by Table 3-1.1 shall be provided so that no travel distance to an extinguisher exceeds 30 ft (9 m).

3-1.4

Where aircraft passenger compartments, galleys, or lounge areas are on a separate level, such compartments or areas shall have extinguishers in accordance with Table 3-1.1.

3-1.5

Extinguishers in passenger compartments shall be readily accessible, mounted for quick removal, and shall be installed on bulkheads wherever possible. Where installation is necessary in overhead storage spaces, extinguishers shall be located so that carry-on luggage cannot interfere with extinguisher accessibility, and extinguisher locations shall be clearly marked and shall be visible to occupants of the compartment.

3-1.6

Personal breathing equipment (PBE) approved and maintained as specified by the authority having jurisdiction shall be provided. The PBE shall be provided within 3 ft (0.9 m) laterally of all hand portable fire extinguishers.

3-2 Cargo Aircraft.

3-2.1 Occupied Spaces on Aircraft.

3-2.1.1 The flight deck of cargo aircraft shall be provided with one Halon 1211 extinguisher.

3-2.2 Cargo Compartment.

3-2.2.1 Where fixed extinguishing systems provide protection for the entire cargo compartment(s), or where cargo compartment(s) are not accessible during flight, hand portable fire extinguishers shall not be required for the cargo compartment(s).

3-2.2.2* Where fixed extinguishing systems do not provide protection for the entire cargo compartment(s), a minimum of one hand portable fire extinguisher having a minimum capacity of 10 lb (4.5 kg) and a minimum rating of 2-A: 40-B:C shall be provided, and shall be equipped with a discharge hose or wand with a minimum length of 12 in. (304 mm).

3-2.2.3 The hand portable fire extinguisher specified in 3-2.2.2 shall be located and accessible inside the cargo compartment at the interior access entry. Any additional hand portable fire extinguishers provided for cargo compartment use shall also be located in the cargo compartment.

3-2.2.4 A self-contained breathing apparatus (SCBA), approved and maintained as specified by the authority having jurisdiction, with a minimum rated service life of 15 min and equipped with a full facepiece shall be provided. The SCBA shall be accessible in a clearly marked location outside the cargo compartment positioned adjacent to the access entry point.

3-3 COMBI Aircraft.

3-3.1

Aircraft hand fire extinguishers shall be placed in the flight deck passenger cabin and cargo compartment on aircraft as specified in Table 3-1.1.

3-3.2

Where an extinguisher other than a water extinguisher is located within 5 ft (1.5 m) of a galley opening and on the same floor level, an additional extinguisher shall not be required for the galley.

3-3.3

The number of hand portable fire extinguishers necessary for the cargo compartment are as specified in Table 3-1.1.

3-3.4

Hand portable fire extinguishers shall be placed adjacent to the entrance door of passenger deck (cargo compartment) and adjacent to the rear exit door of the aircraft.

Chapter 4 Inspection, Maintenance, and Hydrostatic Testing

4-1 Preflight Inspection.

4-1.1

Flight crew member(s) shall make a preflight inspection of all extinguishers.

4-1.2

The inspection shall determine that all required extinguishers are provided, ready for use, in proper location, and properly secured. Where provided, extinguisher pressure gauges shall indicate acceptable pressure, and seals and seal wires shall not be broken.

4-2 Maintenance.

4-2.1

Extinguishers shall be maintained in accordance with Chapter 4 of NFPA 10, *Standard for Portable Fire Extinguishers*, and records shall be kept in accordance with these requirements.

4-2.2

Recharging procedures shall follow the requirements of Chapter 4 of NFPA 10, *Standard for Portable Fire Extinguishers*.

4-2.3

Extinguishers that are out of service for maintenance or recharge shall be replaced with extinguishers having the same agent, rating, and operating procedure.

4-3 Hydrostatic Testing.

4-3.1

Extinguisher shells and appurtenant devices such as nozzles, hoses, and pressure cartridges shall be hydrostatically tested in accordance with Chapter 5 of NFPA 10, *Standard for Portable Fire Extinguishers*.

Chapter 5 Flight Crew Training

5-1 General.

5-1.1

Initially, before assignment, and at least annually thereafter, flight crew members shall receive theoretical and practical training in the basics of fire extinguishment. Instruction on location and use of hand portable fire extinguishers on the aircraft for which flight crew members will be qualified shall be provided.

5-1.2

Training shall be conducted by instructors who are knowledgeable of the aircraft environment experienced in the extinguishment of fire using hand portable fire extinguishers.

5-1.3

Training shall include:

(a) Classroom instruction;

(b) Practical use of hand portable fire extinguishers;

(c) Extinguishment of a hot fire;

(d) Movement in a smoke-filled environment;

(e) Wearing of personal breathing equipment, within a replica of an aircraft cabin environment. Halon shall not be discharged during training, as per 5-3.3.3.

5-2* Classroom/Fire Scenario Instruction.

5-2.1

Classroom instruction shall be given to flight crews concerning all types of extinguishers discussed in this standard. Classroom instruction shall include the following topics as a minimum:

(a) Chemistry of fire and fire extinguishment;

(b) Severity potential of aircraft fires;

(c) Types of combustibles available in aircraft;

(d) Identification and choice of proper extinguisher;

(e) Consequences of misapplication of extinguishers;

(f) Relative effectiveness of extinguishers;

(g) Inspection requirements; and

(h) Health and operational safety concerns.

5-2.2 Practical Smoke Training.

On aircraft types in which it is provided, training shall be given on the use of appropriate breathing equipment (PBE) when using an extinguisher in a cosmetic smoke-filled environment.

5-3 Manipulative Skills Training.

5-3.1

Training shall be administered to flight crews sufficient to have each crew member demonstrate operation and use of hand portable extinguishers.

5-3.2

Training shall be representative of an interior aircraft fire, using the relevant type of hand portable fire extinguishers carried on the aircraft.

5-3.3*

Each flight crew member shall demonstrate the knowledge and skill required to select the appropriate hand portable fire extinguisher for various fire scenarios and to properly apply the agent.

5-3.3.1 The overall training plan shall include representative aircraft fires of Class A, B, C, and combined Class A and B fires.

5-3.3.2 Fire scenarios shall include galley, lavatory or closed compartment, flight deck, open cabins, and flammable liquid fires.

5-3.3.3 Extinguishers containing halon shall not be discharged during routine manipulative skills training. Halon agent shall be conserved and be used only to combat unwanted fires. Suitable substitutes may be used for training. This shall be agreed on with the authority having jurisdiction.

5-3.3.4 Any alternative agent used shall have to be approved by the authority having jurisdiction, listed, and correctly labeled.

5-4* COMBI Aircraft.

5-4.1

The following items shall form the basis of the required course of instruction for flight crew involving COMBI aircraft operations:

(a) Explanation of fire risks with COMBI operations;

(b) Chemistry of fire;

(c) Theory of extinguishing agents;

(d) Aircraft layout;

(e) Cargo loading requirements;

(f) Hazardous cargo consignments;

(g) Scale of COMBI fire fighting equipment (*see Table 3-1.1*);

(h) Designated fire fighter duties

- Preflight audit
- In-flight inspection
- Fire control techniques
- Post fire information feedback;

(i) Practical demonstration and use of portable controlled fire extinguishers;

(j) Practical exercises involving simulated fire situations.

5-4.2

The facility used for training flight crews shall be representative of actual fire conditions to include:

(a) An enclosed environment in which the trainee can experience the effects of fire and heat.

(b) Demonstrate the effectiveness of fire extinguishers when correctly applied to an actual fire.

(c) A facility to demonstrate an electrical fire shall be provided.

(d) One exercise shall include dressing in the protective clothing and personnel breathing equipment provided on-board the aircraft and entering a simulated smoke-filled environment carrying a hand portable fire extinguisher as carried on the aircraft.

5-5 Recurrent Training and Testing.

5-5.1

Recurrent training shall include discussions on recent on-board aircraft fire incidents. This is particularly important when crews are assigned to more than one aircraft type.

5-5.2

Recurrent training shall be provided at intervals not exceeding 3 years.

Chapter 6 Referenced Publications

6-1

The following documents or portions thereof are referenced within this standard and shall be considered part of the requirements of this document. The edition indicated for each reference is the current edition as of the date of the NFPA issuance of this document.

6-1.1 NFPA Publication.

National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.

NFPA 10, *Standard for Portable Fire Extinguishers*, 1994 edition.

6-1.2 Other Publications.

6-1.2.1 UL Publications. Underwriters Laboratories Inc., 333 Pfingsten Road, Northbrook, IL 60062.

ANSI/UL 8, *Standard for Foam Fire Extinguishers*, 1993 edition.

ANSI/UL 299, *Standard for Dry Chemical Fire Extinguishers*, 1993 edition.

ANSI/UL 626, *Standard for 21/2 Gallon Stored Pressure Water-Type Fire Extinguishers*, 1993 edition.

ANSI/UL 711, *Standard for Rating and Fire Testing of Fire Extinguishers*, 1990 edition.

ANSI/UL 1093, *Standard for Halogenated Agent Fire Extinguishers*, 1993 edition.

ANSI/UL 1803, *Standard for Factory Follow-up on Third Party Certified Portable Fire Extinguishers*, 1988 edition.

6-1.2.2 ULC Publications. Underwriters Laboratories of Canada, 7 Crouse Road, Scarborough, ONT M1R 3A9.

CAN/ULC-S504-M88, *Standard for Dry Chemical and Dry Powder Fire Extinguishers*.

CAN4-S507-M83, *Standard for 2 Imperial Gallon Stored Pressure Water Type Fire Extinguishers.*

CAN/ULC-S508-M90, *Rating and Testing of Fire Extinguishers*.

CAN/ULC-S512-M87, *Standard for Dry Chemical Home Type Fire Extinguishers*.

CAN/ULC-8512-M87, *Standard for Halogenated Agent Fire Extinguishers*.

6-1.2.3 U.S. Government Publications. Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402.

Military Specification for Halon 1211, *MIL-B-38741*.

Military Specification for Halon 1301, *MIL-M-12218C*.

Appendix A Explanatory Material

This Appendix is not a part of the requirements of this NFPA document but is included for informational purposes only.

A-1-2.2

In an aircraft fire, the integrity of the aircraft must be preserved and the flight crew must retain their physiological ability to fly the airplane (e.g., vision and consciousness). The overall threat to life must be held at the lowest possible level.

A-1-2.3

Additional information on the effectiveness and suitability of various aircraft hand portable fire extinguishers may be found in DOT/FAA/CT-82/42, "Study of Hand-Held Fire Extinguishers Aboard Civil Aviation Aircraft," 1982.

A-1-3

European fire class designations are as follows:

1. Class A — Wood, paper, cloth, etc;
2. Class B — Flammable liquids;
3. Class C — Flammable gases;
4. Class D — Metal fires;
5. Class E — Electrical fires.

NOTE: European fire extinguisher ratings are not comparable with U.S. or Canadian ratings. In the U.K. the applicable standards are British Standard 5306 - Part 3 - *Selection, Installation, and Maintenance of Portable Fire Extinguishers*, and British Standard 5423 -*Rating Extinguishers by Fire Tests*.

The classification of fire extinguishers consists of one or more LETTERS that indicate the classes of fire on which an extinguisher has been found to be effective. The letters (A and B only) are preceded by a rating NUMBER that indicates the relative extinguishing effectiveness.

A-2-1.3

Aircraft hand portable fire extinguishers must perform in an environment substantially more varied and critical than those approved for use in most land surface applications. Design consideration for extinguisher body, valves, fittings, and associated hardware, including mounting brackets, also should include pressure variations, positive and negative accelerations, vibration, corrosion, and ambient temperature variations.

A-2-1.4

In the United States, the authority having jurisdiction is the Federal Aviation Administration. In Europe it is the Joint Aviation Authority. In Canada it is Transport Canada.

A-2-3.1

Exposure to decomposed halogenated agents may produce varied central nervous system effects depending upon exposure concentration and time. Halogenated agents also will decompose into more toxic products when subjected to flame or hot surfaces at approximately 900°F (482°C). See NFPA 12A, *Standard on Halon 1301 Fire Extinguishing Systems*, and NFPA 12B, *Standard on Halon 1211 Fire Extinguishing Systems*, for detailed information.

A-2-3.4 Halon 1211.

Halon 1211 extinguishers have their greatest effectiveness on Class B and C fires. Extinguishers with 9 lb (4 kg) or greater capacity also are rated for Class A fires. Extinguishers with capacity less than 9 lb (4 kg), although not rated for use on Class A fires, have been shown to be effective in extinguishing surface Class A fires. Detailed information on Halon 1211 agent characteristics, concentration requirements, health hazards, and extinguishing limitations may be found in NFPA 12B, *Standard on Halon 1211 Fire Extinguishing Systems*.

A-2-3.4.1 Halon 1211 extinguishers of less than 9 lb (4 kg) capacity are not always furnished with a discharge hose. However, for access to underseat, overhead, and other difficult-to-reach locations, consideration should be given to using extinguishers with a discharge hose of a minimum length of 12 in. (304 mm). Also, the discharge hose is more likely to result in the extinguisher being properly held in an upright position during use.

A-2-3.4.1.1 For occupied spaces on small aircraft where natural state halon concentrations will be approaching allowable limits, Halon 1301 is the halogenated agent of choice for the following reasons:

(a) Halon 1211 decomposes when exposed to flame, producing toxic products of decomposition. Halon 1211 produces some decomposition products that are not produced by Halon 1301 and is therefore also considered more toxic in the decomposed state.

(b) Health and safety advantages associated with similar volume occupied spaces on larger aircraft (flight decks) do not usually exist for the smaller aircraft. These advantages are a forced ventilation system, availability of oxygen masks, and availability of a second individual capable of flying the aircraft.

A-2-5.1

Dry chemical agent causes visibility problems in occupied spaces and potentially severe contamination of aircraft electrical components.

A-2-6.1

Dry powder agent causes visibility problems in occupied spaces and potentially severe contamination of aircraft electrical components.

A-3-2.2.2 The hose or wand will provide effective reach of the contents of the extinguisher to any part of the cargo.

A-5-2

Discussion of health and safety aspects should include hazards and warnings concerning toxicity of combustion products, as well as the effects of short, intermediate, and long-term exposure to the undecomposed agents. See Appendix A of NFPA 12B, *Standard on Halon 1211 Fire Extinguishing Systems*, as appropriate.

A-5-3.3

It is highly recommended that live fire training on representative aircraft fires be conducted for all flight crew members during both initial and recurrent training sessions. Live fire training provides flight crews with psychological conditioning, fire fighting techniques, and knowledge of extinguishing agent capabilities and limitations under actual fire situations. The live fires used should be the scenarios required in 5-3.3.2.

A-5-4

On completion of the course, flight deck crews and flight attendants should be confident in the procedures and practical use of equipment while working under conditions of smoke and heat. Numbers of personnel receiving training at any one time should be limited in order to ensure that each individual receives adequate practical experience and that his/her performance can be assessed by instructional staff.

Appendix B Referenced Publications

B-1

The following documents or portions thereof are referenced within this standard for informational purposes only and thus are not considered part of the requirements of this document. The edition indicated for each reference is the current edition as of the date of the NFPA issuance of this document.

B-1.1 NFPA Publications.

National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.

NFPA 12A, *Standard on Halon 1301 Fire Extinguishing Systems*, 1992 edition.

NFPA 12B, *Standard on Halon 1211 Fire Extinguishing Systems*, 1990 edition.

B-1.2 British Standards Institution Publications.

British Standards Institution, 2 Park Street, London WIA 2BS, United Kingdom.

British Standard 5306 - Part 3 - *Selection, Installation, and Maintenance of Portable Fire Extinguishers*.

British Standard 5423 - *Rating Extinguishers by Fire Tests*.

B-1.3 Other Publications.

"Study of Hand-Held Fire Extinguishers Aboard Civil Aviation Aircraft;" Krasner, L. M., Final Report, June, 1982; Factory Mutual Research Corporation, 1151 Boston-Providence Turnpike, Norwood, MA 02062; Report Number DOT/FAA/CT-82/42.

"Test and Evaluation of Halon 1211 Hand-Portable Fire Extinguishers for Use in Habitable and Cargo Compartments of USAF Aircraft;" Walker, J. and Vickers, R. N., Final Report November 1981, Engineering Services Laboratory, Air Force Engineering and Services Center, Tyndall Air Force Base; Report Number ESL-TR-81-22.

NFPA 409

1995 Edition

Standard on Aircraft Hangars

1995 Edition

This edition of NFPA 409, *Standard on Aircraft Hangars,* was prepared by the Technical Committee on Airport Facilities and acted on by the National Fire Protection Association, Inc., at its Annual Meeting held May 22-25, 1995, in Denver, CO. It was issued by the Standards Council on July 21, 1995, with an effective date of August 11, 1995, and supersedes all previous editions.

This edition of NFPA 409 was approved as an American National Standard on August 11, 1995.

Origin and Development of NFPA 409

The original fire protection recommendations for the construction and protection of airplane hangars were published by the National Board of Fire Underwriters (now the American Insurance Association) in 1930. Revisions were issued by the NBFU in 1931, 1943, 1945, and 1950. During the period 1943 through 1954, these recommendations were published as NBFU Pamphlet 85. In 1951, the National Fire Protection Association, Inc. organized a Committee on Aircraft Hangars to which the National Board of Fire Underwriters and other interested groups lent their support. The NFPA's first standard was adopted in 1954, and the NBFU adopted the same text, rescinding their earlier 1950 standard. Revisions were made in 1957 and 1958 by this NFPA Committee. In 1959, a reorganization of the NFPA aviation activities resulted in the assignment of this standard to the Sectional Committee on Aircraft Hangars and Airport Facilities. The 1960, 1962, 1965, 1966, 1967, 1969, 1970, 1971, 1972, 1973 and 1975 editions were prepared by this sectional committee. The sectional committee was reorganized as the Technical Committee on Airport Facilities and completed a revision to NFPA 409 in 1978. The document underwent extensive editorial revision and partial technical revision in 1984. This standard was revised in 1990 and 1995.

Technical Committee on Airport Facilities

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Rep. Nat'l Fire Sprinkler Assn.

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Doug Hickey, Transport Canada, ON, Canada

James M. Ingalls, Industrial Risk Insurers, CT
Rep. Industrial Risk Insurers

Elwin G. Joyce, Kentucky Division of Bldg Code Enforcement, KY
Rep. Fire Marshals Assn. of North America

Dennis C. Kennedy, Rolf Jensen & Assoc., Inc., IL

Thomas J. Lett, Albuquerque Fire & Safety Assoc. Inc., NM
Rep. NFPA Fire Service Section

Fred M. Linde, Chubb Nat'l Foam Inc., PA

Edward V. Lockwood, U.S. Army Corps of Engr, VA

Christy J. Marsolo, Grinnell Fire Protection Systems Co., RI

James E. Maurer, Honeywell Inc., CO
Rep. Nat'l Electrical Mfgs. Assn.

John J. O'Sullivan, British Airways, England

Mark Oliszewicz, Schirmer Engineering Corp., IL

Maurice M. Pilette, Mechanical Designs Ltd, MA

Jack Poole, Poole Fire Protection Engr, Inc., KS

Randy D. Pope, Burns & McDonnell Engineering Co., MO

Alan Rhome, The Port Authority of NY & NJ, NY
Rep. Airport Operators Council Int'l, Inc.

Doug Toupalik, Ansul Fire Protection/Wormald U.S., Inc., WI
Rep. Fire Equipment Mfrs. Assn. Inc.

Terry L. Victor, Automatic Sprinkler Corp. of America, MD

Fred K. Walker, U.S. Air Force, FL

Alternates

Michael E. Aaron, Rolf Jensen & Assoc., Inc., IL
(Alt. to D. C. Kennedy)

Joseph A. Behnke, Ansul Fire Protection, WI
(Alt. to D. Toupalik)

Thomas G. Burk, Federal Express Corp., TN
(Alt. to D. R. Chase, Jr.)

Jeffrey W. DeLong, Industrial Risk Insurers, CA
(Alt. to J. M. Ingalls)

James Devonshire, Chubb Nat'l Foam, PA
(Alt. to F. M. Linde)

Robert D. Grausam, Kemper Nat'l Insurance Cos., NY
(Alt. to J. D. Dick)

Kevin M. Green, Schirmer Engineering Corp., CA

(Alt. to M. Oliszewicz)

Frank M. E. Hughes, British Airways, England
(Alt. to J. J. O'Sullivan)

Keith C. Kremkow, Johnson & Higgins, IL
(Alt. to P. F. Helweg, Jr.)

John E. Loehle, Air Nat'l Guard Readiness Center, MD
(Alt. to F. K. Walker)

Rahe Loftin, Carter & Burgess, Inc., TX
(Alt. to D. J. Burkhart)

Al Mazur, Transport Canada, ON, Canada
(Alt. to D. Hickey)

Robert C. Merritt, Factory Mutual Research Corp., MA
(Alt. to L. M. Krasner)

V. G. Pyrpyris, The Port Authority of NY & NJ, NY
(Alt. to A. Rhome)

John B. Ramsey, The Viking Corp., MI
(Alt. to J. Golinveaux)

Nonvoting

J. Walter Coon, Black & Veatch, MO
(Member Emeritus)

Jerome Lederer, Laguna Hills, CA
(Member Emeritus)

Mark T. Conroy, NFPA Staff Liaison

This list represents the membership at the time the Committee was balloted on the text of this edition. Since that time, changes in the membership may have occurred.

NOTE: Membership on a Committee shall not in and of itself constitute an endorsement of the Association or any document developed by the Committee on which the member serves.

Committee Scope: This Committee shall have primary responsibility for documents on fire safety for the construction and protection at airport facilities involving construction engineering but excluding airport fixed fueling systems.

NFPA 409
Standard on
Aircraft Hangars

1995 Edition

NOTICE: An asterisk (*) following the number or letter designating a paragraph indicates explanatory material on that paragraph in Appendix A.
Information on referenced publications can be found in Chapter 7 and Appendix B.

Chapter 1 Administration

1-1 Scope.

This standard contains the minimum requirements for the proper construction and protection of aircraft hangars from fire.

1-2 Purpose.

1-2.1*

The purpose of this standard is to provide a reasonable degree of protection from fire for life and property in aircraft hangars, based on sound engineering principles, test data, and field experience.

1-2.2

No part of this standard is intended to restrict new technologies or alternate arrangements, provided the level of safety prescribed by the standard is not lowered.

1-3 Definitions.

Aircraft Access Door. Any opening through which any portion of the aircraft is passed to gain entry to the hangar.

Aircraft Hangar. A building or other structure inside any part of which aircraft are housed or stored, and in which aircraft might undergo service, repairs, or alterations. For the purposes of this standard, aircraft hangars are classified as follows:

Group I Aircraft Hangar. A hangar having at least one of the following features and operating conditions:

(a) An aircraft access door height over 28 ft (8.5 m),

(b) A single fire area in excess of 40,000 ft^2 (3716 m^2), or

(c) Provision for housing an aircraft with a tail height over 28 ft (8.5 m).

Group II Aircraft Hangar. A hangar having both of the following features:

(a) An aircraft access door height of 28 ft (8.5 m) or less, and

(b) A single fire area for specific types of construction in accordance with Table 1-3.

Table 1-3

Single Fire Area

Type of Construction	Equal or Greater Than Ft^2	Equal or Greater Than (M^2)	But Not Larger Than Ft^2	But Not Larger Than (M^2)
Type I (443) and (332)	30,001	(2,787)	40,000	(3,716)
Type II (222)	20,001	(1,858)	40,000	(3,716)
Type II (111), Type III (211), and Type IV (2HH)	15,001	(1,394)	40,000	(3,716)
Type II (000)	12,001	(1,115)	40,000	(3,716)
Type III (200)	12,001	(1,115)	40,000	(3,716)
Type V (111)	8,001	(743)	40,000	(3,716)
Type V (000)	5,001	(465)	40,000	(3,716)

Group III Aircraft Hangar.* A Group III hangar can be a freestanding unit for a single aircraft, a row hangar with a common structural wall and roof system, and a hanger that houses multiple aircraft as well as having door openings for each aircraft, or an open bay hangar capable of housing multiple aircraft.

A Group III hangar shall have both of the following features:

(a) An aircraft access door height of 28 ft (8.5 m) or less, and

(b) A single fire area that measures up to the maximum square footage permitted for specific types of construction in accordance with Table 1-3(a).

Table 1-3(a) Maximum Fire Areas for Group III Hangars

Type of Construction	Maximum Single Fire Area Ft^2	(M^2)
Type I (443) and (332)	30,000	(2,787)
Type II (222)	20,000	(1,858)
Type II (111), Type III (211), and Type IV (2HH)	15,000	(1,394)
Type II (000)	12,000	(1,115)
Type III (200)	12,000	(1,115)
Type V (111)	8,000	(743)
Type V (000)	5,000	(465)

Aircraft Storage and Servicing Area. That part of a hangar normally used for the storage and servicing of one or more aircraft, not including any adjacent or contiguous areas or structures, such as shops, storage areas, and offices.

Approved.* Acceptable to the authority having jurisdiction.

Authority Having Jurisdiction.* The organization, office, or individual responsible for approving equipment, an installation, or a procedure.

Demand Calculation Method. Hydraulic calculation procedure for determining the minimum theoretical flow and pressure required to produce a minimum specified total discharge from a specific configuration of piping and discharge devices.

Detection System. A system consisting of detectors; controls; control panels; automatic and manual actuating mechanisms; all wiring, piping, and tubing; and all associated equipment that is used to actuate an extinguishing system.

Fire Area. An area within an aircraft hangar subject to loss by a single fire because of lack of internal subdivisions as specified in Section 2-2 or Section 5-2 of this standard, as appropriate.

Fire Wall. A wall separating buildings or subdividing a building to prevent the spread of fire and having a fire resistance rating and structural stability.

Foam-Water Deluge System. A system having a pipe connected to and including a source of foam concentrate and a water supply. Water and foam concentrate [protein, fluoroprotein, or aqueous film-forming foam (AFFF)] are delivered to open discharge devices for extinguishing agent discharge and for distribution over the area to be protected. The piping is connected to the water supply through an automatic valve that is actuated by the operation of a detection system installed in the same areas as the discharge devices. When this valve opens, water flows into the piping system, foam concentrate is injected into the water, and the resulting discharge of foam solution through the foam-water discharge devices generates and distributes foam. Upon exhaustion of the foam concentrate supply, water discharge will follow the foam and continue until shut off manually.

Hangar Building Cluster. A group of buildings with more than one area for the storage and servicing of aircraft and all attached or contiguous structures, or structures not separated as specified in 2-3.2 or 5-2.1 of this standard, as appropriate.

Listed.* Equipment or materials included in a list published by an organization acceptable to the authority having jurisdiction and concerned with product evaluation that maintains periodic inspection of production of listed equipment or materials and whose listing states either that the equipment or material meets appropriate standards or has been tested and found suitable for use in a specified manner.

Shall. Indicates a mandatory requirement.

Should. Indicates a recommendation or that which is advised but not required.

Single Hangar Building. A building with one area for the storage and servicing of aircraft and any attached, adjoining, or contiguous structure, such as a lean-to, shop area, or parts storage area not separated as specified in 2-3.2 or 5-2.1 of this standard, as appropriate.

Supply Calculation Method. Hydraulic calculation procedure for determining the maximum theoretical flows and pressures in a system with a specific configuration of piping and discharge devices supplied by a water distribution system.

Unfueled Aircraft. An aircraft whose fuel system has had flammable or combustible liquid removed such that no tank, cell, or piping contains more than $^1/_2$ percent of its volumetric capacity.

Tail Height. The maximum tail height as stated in aircraft manufacturers' specifications.

Chapter 2 Construction of Group I and Group II Aircraft Hangars

2-1 Types of Construction.

2-1.1*

Group I hangars shall be either Type I or Type II construction in accordance with NFPA 220, *Standard on Types of Building Construction*. Group II hangars shall be constructed of any of the types of construction specified in NFPA 220, *Standard on Types of Building Construction*, or any combination thereof.

2-1.2*

Mezzanines, tool rooms, and other enclosures within aircraft storage and servicing areas shall be constructed of noncombustible material or limited-combustible material as defined in NFPA 220, *Standard on Types of Building Construction*, in all hangars except those of Type V (111) and (000) construction.

2-2 Internal Separations.

2-2.1*

Where aircraft storage and servicing areas are subdivided into separate fire areas, the separation shall be by a fire wall having not less than a 3-hour fire resistance rating. Any openings in such fire walls communicating directly between two aircraft storage and servicing areas shall be provided with a listed 3-hour fire door or 3-hour shutter actuated from both sides of the wall. Where areas are of different heights, the tallest wall shall have a fire resistance rating of not less than 3 hours.

2-2.2

Where two or more aircraft storage and servicing areas constituting separate fire areas are separated by continuous offices, shops, and parts storage areas, one of the two walls between the aircraft storage and servicing areas and the offices, shops, and parts storage areas shall comply with 2-2.1. The other wall shall comply with 2-2.3.

2-2.3*

Partitions and ceilings separating aircraft storage and servicing areas from all other areas, shops, offices, and parts storage areas shall have at least a 1-hour fire resistance rating with openings protected by listed fire doors or shutters having a minimum fire resistance rating of 45 minutes.

2-2.4

Where a storage and servicing area has an attached, adjoining, or contiguous structure, such as a lean-to, shop, office, or parts storage area, the wall common to both areas shall have at least a 1-hour fire resistance rating, with openings protected by listed fire doors having a minimum fire resistance rating of 45 minutes and actuated from both sides of the wall.

2-3 Clear Space Distance Requirements Around Hangars.

2-3.1

Precautions shall be taken to ensure ready access to hangars from all sides. Adequate separation shall be provided to reduce fire exposure between buildings. The clear spaces specified in Tables 2-3.2 and 2-3.3 shall not be used for the storage or parking of aircraft or concentrations of combustible materials, nor shall buildings of any type be erected therein.

2-3.2

For single hangar buildings, the clear space distances specified in Table 2-3.2 shall be maintained on all sides of the single hangar. Where mixed types of construction are involved, the less fire-resistant type of construction shall be used to determine the clear space required. Where the minimum clear space specified in Table 2-3.2 is not met, the buildings shall be considered a hangar building cluster.

Table 2-3.2

Type of Construction	Minimum Separation Required
Type I (443) and (332)	50 ft (15m)
Type II (222)	50 ft (15m)
Type II (111), Type III (211), and Type IV (2HH)	50 ft (15 m)
Type II (000)	50 ft (15 m)
Type III (200)	50 ft (15 m)
Type V (111) and (000)	75 ft (23 m)

2-3.2.1 Where both exposing walls and openings therein of adjacent single hangar buildings have a minimum fire resistance rating of at least 3 hours, no minimum separation distance shall be required. These buildings shall be considered a hangar building cluster.

2-3.2.2 Where the exposing wall and any openings therein of one hangar have a minimum fire resistance rating of at least 2 hours, the minimum separation distance shall be permitted to be reduced to not less than 25 ft (7.5 m) for single hangar buildings.

2-3.2.3* Where the exposing walls of both buildings have a minimum fire resistance rating of at least 2 hours, with all windows protected by listed glass in fixed steel sash having a minimum fire resistance rating of $^{3}/_{4}$ hour, with outside sprinkler protection and each doorway protected with one automatically operated listed fire door having a minimum fire resistance rating of $1^{1}/_{2}$

hours, the clear space distance shall be permitted to be reduced to not less than 25 ft (7.5 m) between single hangar buildings. Under such conditions, the glass area in the exposing walls shall be not more than 25 percent of the wall area.

2-3.3

The clear space distances specified in Table 2-3.3 shall be maintained on all sides of the hangar building clusters. Where mixed types of construction are involved, the less fire-resistant type of construction shall be used to determine required clear space differences.

Table 2-3.3

Type of Construction	Minimum Separation Required
Type I (443) and (332)	75 ft (23 m)
Type II (222)	75 ft (23 m)
Type IV (2HH)	75 ft (23 m)
Type II (III) and Type III(211)	100 ft (30 m)
Type II (000)	100 ft (30 m)
Type III (200)100 ft (30 m)	100 ft (30m)
Type V (III) and (000)	125 ft (38 m)

2-3.3.1 Where the exposing wall and any openings therein of one hangar have a minimum fire resistance rating of at least 2 hours, the clear space distance shall be permitted to be reduced to not less than 50 ft (15 m) between hangar building clusters.

2-3.3.2* Where the exposing walls of both buildings have a minimum fire resistance rating of at least 2 hours, with all windows protected by listed glass in fixed steel sash having a minimum fire resistance rating of hour, with outside sprinkler protection and each doorway protected with one automatically operated listed fire door having a minimum fire resistance rating of $1^1/_2$ hours, the clear space shall be permitted to be reduced to not less than 50 ft (15 m) between hangar building groups. Under such conditions, the glass area in the exposing walls shall be not more than 25 percent of the wall area.

2-4 Floors.

2-4.1

The surface of the grade floor of aircraft storage and servicing areas, regardless of type of hangar construction, shall be noncombustible and above the grade of the approach or apron at the entrance to the hangar.

2-4.2*

The floors of adjoining areas that pose flammable or combustible liquid spill hazards, and connect with aircraft storage and servicing areas, shall be noncombustible and shall be designed to prevent a spill from entering the aircraft storage and servicing area.

2-4.3

Floor openings in multistoried sections of hangars shall be enclosed with partitions or protected with construction having a fire resistance rating not less than that required for the floor construction where the opening is made.

2-5 Roofs.

2-5.1

Roof coverings shall be of an approved type of tile, slate, metal, or asphalt shingle, or of built-up roofing finished with asphalt, slate, gravel, or other approved material. Roof coverings shall be listed as Class A or Class B when tested in accordance with NFPA 256, *Standard Methods of Fire Tests of Roof Coverings*.

2-5.2

Where insulated metal deck assemblies are used, they shall be equivalent to FM Class 1, or UL Fire Classified ratings.

2-5.3*

Spaces under roofs created where suspended ceilings are provided in aircraft storage and servicing areas shall be cut off from the area below so that the space cannot be used for storage or other occupancy. The space shall be provided with ventilation louvers to ensure air circulation therein.

2-5.4

Permanent exterior ladders to hangar roofs shall be provided on all hangars exceeding 25,000 ft^2 (2323 m^2) in area, or exceeding 40 ft (12 m) in height, or exceeding 100 ft (30 m) in their smallest dimension.

Exception: Permanent exterior ladders to hangar roofs shall not be required where enclosed stairs leading directly to the roof of aircraft storage and servicing areas are available from the exterior of the hangar.

2-6 Columns.

2-6.1

In aircraft storage and servicing areas of hangars housing other than unfueled aircraft, column protection shall be required in accordance with 2-6.2 through 2-6.4.

2-6.2

All main steel structural columns of the aircraft storage and servicing areas shall be made fire resistant using listed materials and methods to provide a fire-resistive rating of not less than 2 hours.

2-6.3*

Fixed water or foam-water systems shall be permitted to be used in lieu of a 2-hour fire resistance rating, if such systems are designed specifically to protect the columns.

2-6.4

All fire-resistant materials used to protect structural steel columns shall be of a type that resists damage from discharge of the fixed fire protection system.

2-7 Doors.

2-7.1

Hangar doors that accommodate aircraft shall be of noncombustible construction where hangars are of any Type I or Type II construction as specified in 2-1.1 of this chapter.

2-7.2

The power source for hangar doors shall operate on independent circuits and shall not be deenergized when the main disconnect switches for general hangar power are shut off.

2-7.3*

Vertical traveling doors shall be counterbalanced, and horizontal slide or accordion-type doors shall be arranged, so that manual or auxiliary operation by means of winches or tractors, for example, is feasible.

2-7.4

In areas where freezing temperatures can occur, door tracks or the bottom edges of doors shall be protected by heating coils or equivalent means to prevent ice formation that might prevent or delay operation.

2-8 Curtains.

Where curtains are used to enclose a work area, they shall be of a listed flame-retardant type.

2-9 Landing Gear Pits, Ducts, and Tunnels.

2-9.1*

Landing gear pits, ducts, and tunnels located below floor level shall be designed on the premise that flammable liquids and vapor will be present at all times. Materials and equipment shall be impervious to liquids and shall be fire resistant or noncombustible.

2-9.2

Electrical equipment for all landing gear pits, ducts, and tunnels located below hangar floor level shall be suitable for use in Class I, Division 1, Group D hazardous locations in compliance with Article 501 of NFPA 70, *National Electrical Code*®.

2-9.3

All landing gear pits, ducts, and tunnels shall be provided with a positive mechanical exhaust ventilation system capable of providing a minimum rate of five air changes per hour during normal operations and be designed to discharge externally to the hangar.

2-9.4

Upon the detection of flammable vapors, the ventilation system shall be capable of providing a minimum ventilation rate of 30 air changes per hour for the landing gear pit and all associated ducts or tunnels.

2-9.5

The ventilation system shall be controlled by an approved continuous-reading combustible gas analyzing system that is arranged to operate the ventilation system at the rate specified in 2-9.4 automatically upon detection of a specified flammable vapor concentration that is below the lower flammable limit. The detection system shall have sensors located throughout all ducts and tunnels.

2-9.6

As entry of fuel, oil, and water into landing gear pits is inevitable, drainage or pumping facilities shall be provided. Water-trapped vapor seals and appropriate separator fuel traps shall be provided. Where automatic pumping facilities are necessary, they shall be suitable for use with aviation fuel and water. The drainage shall be fully enclosed pipe runs if drainage is routed through ventilation or access tunnels to external discharge points.

2-9.7*

Explosion protection shall be provided in landing gear pits and communicating ducts and tunnel areas in the form of pressure-relief venting or by a listed explosion prevention system installed in accordance with NFPA 69, *Standard on Explosion Prevention Systems*.

2-9.8*

An approved fire protection system shall be installed to protect each pit unless the hangar fire protection required by either Chapter 3 or Chapter 4 of this standard is adequate to protect each pit.

2-10 Exposed Interior Insulation.

2-10.1

Exposed interior insulation attached to walls and roofs in an aircraft storage and servicing area of a hangar not provided with a sprinkler system designed in accordance with Chapter 3 or Chapter 4 of this standard, as applicable, shall be noncombustible as defined in Chapter 2 of NFPA 220, *Standard on Types of Building Construction*.

2-10.2

In an aircraft storage and servicing area of a hangar equipped with an approved sprinkler system designed in accordance with Chapter 3 or Chapter 4 of this standard, as applicable, exposed interior insulation attached to walls and roofs shall be noncombustible or limited-combustible as defined in Chapter 2 of NFPA 220, *Standard on Types of Building Construction*.

2-11 Drainage of Aprons and Hangar Floors.

2-11.1

The apron or approach at the entrance to the hangar shall slope away from the hangar with a minimum grade of one-half of one percent (1:200) for the first 50 ft (15 m). Ramps used for aircraft fueling adjacent to hangar structures shall comply with NFPA 415, *Standard on Aircraft Fueling Ramp Drainage*. In establishing locations for nearby aircraft parking, consideration shall be given to the drainage pattern of the apron.

2-11.2 Hangar Floor Drainage.

2-11.2.1 In aircraft storage and servicing areas of hangars housing other than unfueled aircraft floor drainage in accordance with 2-11.2.2 through 2-11.2.12 shall be provided.

2-11.2.2* Floor drainage systems shall be provided to restrict the spread of fuel in order to reduce the fire and explosion hazards from fuel spillage.

2-11.2.3 Drainage systems shall be designed to reduce fire and explosion hazards within the systems to the maximum extent by the use of noncombustible underground piping, and by routing drainage as directly as possible to a safe outside location. Such systems shall be designed with suitable traps or be provided with adequate ventilation to prevent vapor mixtures from forming within the underground drainage system.

2-11.2.4* Drainage systems in aircraft storage or servicing areas shall be designed and constructed so that they have sufficient capacity to prevent buildup of flammable liquids and water over the drain inlet when all fire protection systems and hose streams are discharging at the design rate.

2-11.2.5 The pitch of the floor shall be a minimum of one-half of one percent. The floor pitch provided shall be calculated taking into consideration the towing requirements of the aircraft and the factors of aircraft weight, balance checking, and maintenance.

2-11.2.6 Each drainage system shall be calculated separately, taking into consideration the maximum rated discharge based on the supply calculation method for the fire protection systems and hose lines.

2-11.2.7 The size of drainage piping shall be determined by the hydraulic demands placed on the system throughout its length.

2-11.2.8 Curbs, ramps, or drains shall be provided at all openings from aircraft storage and servicing areas, or the slope of the floor shall be such so as to prevent the flow of liquids through openings.

2-11.2.9 Pits for service facilities, such as for compressed air, electrical outlets, etc., shall drain into the floor drainage system.

2-11.2.10 Oil separators shall be provided for the drainage systems serving all aircraft storage and servicing areas. These separators can serve each hangar drainage system, a group of hangar drainage systems, or be installed as part of a general airport drainage system.

2-11.2.11 In aircraft storage and servicing areas protected by water sprinkler systems or foam-water systems, a bypass shall be provided around the separator to allow for emergency direct disposal of water and flammable liquids. Separator systems shall discharge flammable liquid products to a safely located tank, cistern, or sump.

2-11.2.12 Grates and drain covers shall be of sufficient strength to support the point loading of the heaviest type aircraft or equipment that the hangar might serve. Grates and covers shall be removable to facilitate cleaning and flushing.

2-12 Heating and Ventilating.

2-12.1*

Heating, ventilating, and air conditioning equipment shall be installed, as applicable, in accordance with NFPA 90A, *Standard for the Installation of Air Conditioning and Ventilating Systems*; NFPA 31, *Standard for the Installation of Oil-Burning Equipment*; NFPA 54, *National Fuel Gas Code*; NFPA 90B, *Standard for the Installation of Warm Air Heating and Air Conditioning Systems;* and NFPA 58, *Standard for the Storage and Handling of Liquefied*

Petroleum Gases.

2-12.2

In aircraft storage and servicing areas of hangars housing other than unfueled aircraft, or sections communicating therewith, no heating, ventilating, and air conditioning equipment employing an open flame or glowing element shall be installed, other than as provided for in 2-12.5 of this section.

2-12.3

In aircraft storage and servicing areas of hangars housing other than unfueled aircraft, hangar heating plants that are fired with gas, liquid, or solid fuels not covered under 2-12.5 of this section and that are not located in a detached building shall be located in a room separated from other parts of the hangar by construction having at least a 1-hour fire resistance rating. This separated room shall not be used for any other hazardous purpose or combustible storage, and shall have no direct access from the aircraft storage or servicing area. Openings in the walls of such rooms communicating with other portions of the hangar shall be restricted to those necessary for ducts or pipes. Penetrations of the 1-hour fire resistance rated enclosure shall be firestopped with an approved material properly installed and capable of maintaining the required fire resistance rating for the enclosure. Each such duct shall be protected with a listed automatic fire damper or door. All air for combustion purposes entering such separated rooms shall be drawn from outside the building.

2-12.4*

In aircraft storage and servicing areas of hangars housing other than unfueled aircraft, heating, ventilating, and air conditioning systems employing recirculation of air within aircraft storage and servicing areas shall have return air openings not less than 10 ft (3 m) above the floor. Supply air openings shall not be installed in the floor and shall be at least 6 in. (152 mm) from the floor measured to the bottom of the opening.

Where automatic fire protection systems are installed in aircraft storage and servicing areas, fans for furnace heating systems shall be arranged to shut down automatically by means of the operations of the interior automatic fire protection system. One or more manual fan shutoff switches shall be provided. Shutoff switches shall be accessible and clearly placarded.

2-12.5 Suspended or Elevated Heaters.

2-12.5.1 In aircraft storage and servicing areas of hangars housing other than unfueled aircraft, listed electric, gas, or oil heaters shall be permitted to be used if installed as specified in 2-12.5.2, 2-12.5.3, and 2-12.5.4.

2-12.5.2 In aircraft storage and servicing areas, heaters shall be installed at least 10 ft (3 m) above the upper surface of wings or of the engine enclosures of the highest aircraft that might be housed in the hangar. The measurement shall be made from the wing or engine enclosure, whichever is higher from the floor, to the bottom of the heater.

2-12.5.3 In shops, offices, and other sections of aircraft hangars communicating with aircraft storage or servicing areas, the bottom of the heaters shall be installed not less than 8 ft (2.4 m) above the floor.

2-12.5.4 In all hangars, suspended or elevated heaters shall be located in spaces where they shall not be subject to injury by aircraft, cranes, movable scaffolding, or other objects. Provisions shall be made to ensure accessibility to suspended heaters for recurrent maintenance purposes.

2-12.6

Where a mechanical ventilating system is employed in hangars or shops, the ventilating system shall be installed in accordance with NFPA 90A, *Standard for the Installation of Air Conditioning and Ventilating Systems*.

2-12.7

Where blower and exhaust systems are installed for vapor removal, the systems shall be installed in accordance with NFPA 91, *Standard for Exhaust Systems for Air Conveying of Materials*.

2-13 Lighting and Electrical Systems.

2-13.1

Artificial lighting shall be restricted to electric lighting.

2-13.2*

Electrical services shall be installed in compliance with the provisions for aircraft hangars contained in Article 513 of NFPA 70, *National Electrical Code*.

2-13.3

In aircraft storage and servicing areas of hangars housing other than unfueled aircraft, main distribution panels, metering equipment, and similar electrical equipment shall be located in a room separated from the aircraft storage and servicing areas by a partition having at least a 1-hour fire resistance rating. The partition shall not be penetrated except by electrical raceways, which shall be protected by approved sealing methods maintaining the same fire resistance rating as the partition.

2-14* Lightning Protection.

Where provided, lightning protection shall be installed in accordance with NFPA 780, *Standard for the Installation of Lightning Protection Systems*.

2-15 Grounding Facilities for Static Electricity.

2-15.1*

Aircraft storage and servicing areas of hangars housing other than unfueled aircraft shall be provided with grounding facilities for removal and control of static electrical accumulations on aircraft while aircraft are stored or undergoing servicing in a hangar in accordance with 2-15.2 and 2-15.3.

2-15.2

An adequate number of floor-grounding receptacles shall be provided. The receptacles shall be either grounded through individual driven electrodes or electrically bonded together in a grid system and the entire system grounded to underground metal piping, such as cold water or sprinkler piping, or driven electrodes. Where driven electrodes are used, they shall consist of $^5/_8$ in. (15.9 mm) diameter or larger metal rods driven at least 5 ft (1.5 m) into the ground. Floor-grounding receptacles shall be designed to minimize the tripping hazard.

2-15.3*

Grounding wires shall be bare and of a gauge that is satisfactorily durable to withstand mechanical strains and usage.

2-16 Exit and Access Requirements.

2-16.1

Means of egress from the aircraft hangar shall comply with NFPA *101®*, *Life Safety Code®*.

2-16.2

Aisles and clear space shall be maintained to ensure access to sprinkler control valves, standpipe hose, fire extinguishers, and similar equipment.

2-17* Materials for Draft Curtains.

Where provided, draft curtains shall be constructed of noncombustible materials not subject to disintegration or fusion during the early stages of a fire and shall be tightly fitted to the underside of the roof or ceiling. Any opening in draft stops shall be provided with self-closing doors constructed of materials equivalent in fire resistance to the draft stop itself.

Chapter 3 Protection of Group I Aircraft Hangars

3-1 General.

3-1.1

Group I aircraft hangar storage and servicing areas of hangars housing other than unfueled aircraft shall be equipped with an approved automatic foam-water deluge system, as specified in Section 3-2 of this chapter, as the primary protection system. In addition, a supplementary protection system as specified in Section 3-3 of this chapter shall also be provided where applicable.

3-1.2

Group I aircraft hangar storage and service areas housing unfueled aircraft shall be provided with automatic sprinkler protection as specified in Sections 4-2 and 4-7.

3-1.3

Automatic sprinkler protection shall be provided inside separate shop, office, and storage areas located inside aircraft maintenance and servicing areas, unless they are otherwise provided with automatic fire protection systems.

3-1.4

Each sprinkler system shall be designed and installed in accordance with NFPA 13, *Standard for the Installation of Sprinkler Systems*, and NFPA 16, *Standard for the Installation of Deluge Foam-Water Sprinkler and Foam-Water Spray Systems*, as applicable, and in accordance with the requirements of this chapter.

3-1.5

Additional protection, as specified in Sections 3-4 and 3-6 of this chapter, shall be provided in all Group I aircraft hangars in addition to other protection systems required by this chapter.

3-2 Deluge Foam-Water Sprinkler System Design and Performance.

3-2.1 Plans and Specifications.

3-2.1.1* Before systems are installed, complete specifications and working plans shall be drawn to scale showing all essential details, and plans shall be easily reproducible to provide necessary copies.

3-2.1.2 Information supplied in these plans and specifications shall be in accordance with NFPA 13, *Standard for the Installation of Sprinkler Systems*, and shall include the following:

(a) The design purpose of the system;

(b) The discharge densities and the period of discharge;

(c) The hydraulic calculations;

(d) The details of tests of the available water supply;

(e) The details of proposed water supplies;

(f) The detailed layout of the piping and of the detection systems;

(g) The make and type of discharge devices, operating equipment, and foam concentrate to be installed;

(h) The location and spacing of discharge devices;

(i) The pipe hanger and bracing location and installation details;

(j) The location of draft curtains;

(k) The accurate and complete layout of the area to be protected; and

(l) The details of any foam concentrate, its storage and injection, and other pertinent data to provide a clear explanation of the proposed design.

3-2.2 Pipe and Fittings.

Piping and fitting materials shall be in accordance with NFPA 16, *Standard for the Installation of Deluge Foam-Water Sprinkler and Foam-Water Spray Systems*.

3-2.2.1 In aircraft storage and servicing areas, each sprinkler system shall be designed in accordance with NFPA 13, *Standard for the Installation of Sprinkler Systems*, and NFPA 16, *Standard for the Installation of Deluge Foam-Water Sprinkler and Foam-Water Spray Systems*, as applicable, and in accordance with this chapter.

3-2.2.2* In aircraft storage and servicing areas, the maximum projected floor area under an individual deluge system shall not exceed 15,000 ft^2 (1394 m^2).

3-2.2.3 In aircraft storage and servicing areas, the protection area as projected on the floor shall be limited to 130 ft^2 (12.1 m^2). The maximum distance between sprinklers either on branch lines or between branch lines shall be 12 ft (3.7 m).

3-2.2.4 System piping shall be hydraulically designed using two separate calculation methods. The demand calculation method shall be performed to determine the adequacy of the water supply. The supply calculation method shall be performed to determine the amount of foam concentrate required. Where steel pipe is installed, the coefficient C in the Hazen and Williams formula shall be taken as 120 in the calculations.

3-2.2.5 In other portions of hangars protected by sprinklers, the spacing shall be in accordance with the hazard requirements of the areas involved.

3-2.2.6 Uniform sprinkler discharge shall be based on a maximum variation of 15 percent between the sprinkler providing the lowest density and the sprinkler providing the greatest density within an individual deluge system as specified in 3-2.2.12 or 3-2.2.13. Variation below the required density shall not be permitted. Orifice plates, sprinklers of different orifice sizes, piping of less than 1 in. diameter, or multiple fittings installed between a branch line fitting and an individual sprinkler for the sole purpose of increasing pressure loss shall not be permitted as a means to limit discharge.

Exception: Local application protection for columns.

3-2.2.7 Where open hangar doors result in interference with the distribution of overhead systems, additional devices shall be provided to ensure effective floor coverage.

3-2.2.8 Foam-water deluge systems discharge devices shall be either air-aspirating or non air-aspirating and shall have deflectors designed to produce water discharge patterns closely comparable to those of spray sprinklers as defined in NFPA 13, *Standard for the Installation of Sprinkler Systems*, when discharging at the same rates of flow.

3-2.2.9 The discharge devices shall generate foam where supplied with the foam solution under pressure and shall distribute the foam in a pattern essentially similar to that of water discharging therefrom.

3-2.2.10 The discharge devices shall have a minimum nominal $^1/_4$-in. (6.4-mm) orifice and shall be listed for use with the particular type of foam concentrate to be used in the system.

3-2.2.11 Strainers shall be installed in accordance with NFPA 16, *Standard for the Installation of Deluge Foam-Water Sprinkler Systems and Foam-Water Spray Systems*.

3-2.2.12 The discharge density from air-aspirating discharge devices using protein-type, fluoroprotein-type, or AFFF-type foam solutions shall be a minimum of 0.20 gal of foam solution per min per ft^2 (8.1 L/min/m^2) of floor area.

3-2.2.13 The discharge density from non air-aspirating discharge devices using AFFF-type foam solutions shall be a minimum of 0.16 gal of foam solution per min per ft^2 (6.5 L/min/m^2) of floor area.

3-2.3* Foam Concentrate Supply.

3-2.3.1 The quantities of foam concentrate, either protein foam, fluoroprotein, or AFFF, shall be sufficient for a 10-minute foam discharge based on the supply calculation in 3-2.2.4.

3-2.3.2 A reserve supply of foam concentrate of compatible type for the system shall be directly connected to the system and readily available. The reserve supply shall be in the same quantity as the main supply.

To prevent accidental depletion of this reserve supply, it shall be available to the system only by intentional manual operation.

3-2.4 Foam Concentrate Pumps.

3-2.4.1* Where foam concentrate is introduced into the water stream by pumping, the total foam concentrate pumping capacity shall be such that the maximum flows and pressures can be met with the largest foam concentrate pump out of service.

3-2.4.2 Power supply for the drivers of foam concentrate pumps shall be installed in accordance with NFPA 20, *Standard for the Installation of Centrifugal Fire Pumps*, and NFPA 70, *National Electrical Code.*

Power supplies shall be arranged such that disconnecting power to the protected facility during a fire shall not disconnect the power supply to the foam concentrate pump feeder circuit.

3-2.4.3 Controllers for foam concentrate pumps shall be as follows:

(a) For electric drive foam concentrate pumps greater than 30 horsepower, a listed fire pump controller shall be used.

(b) For electric drive foam concentrate pumps greater than 15 horsepower but not exceeding 30 horsepower, a listed fire pump controller or listed limited service controller shall be used.

(c) For electric drive foam concentrate pumps less than 15 horsepower, a listed limited service controller shall be used.

(d) For diesel engine drive foam concentrate pumps, a listed fire pump controller shall be used.

3-2.4.4 Piping shall be arranged so that maximum foam concentrate demand can be supplied from either primary or reserve foam concentrate tanks.

3-2.5 Water Supply.

3-2.5.1* The water supply shall be capable of furnishing water for the largest number of systems that possibly could be expected to operate.

3-2.5.1.1 Where draft curtains meeting the requirements of Section 2-17 are not provided, water supply requirements shall be calculated on the premise that all systems in the aircraft storage and servicing area not subdivided by fire walls will operate.

3-2.5.1.2 In aircraft storage and servicing areas having a maximum roof or ceiling height of 25 ft (7.5 m) or less, the water supply shall be sufficient for the operation of the largest number of systems. Sufficient water supply requirements are determined by assuming that a fire at any point will operate all the systems in every draft-curtained area that is wholly or partially within a 50-ft (15-m) radius of that point measured horizontally.

3-2.5.1.3 In aircraft storage and servicing areas having a maximum roof or ceiling height in excess of 25 ft (7.5 m) but not more than 75 ft (22.5 m) above floor level, the water supply shall be sufficient for the operation of the largest number of systems. Sufficient water supply requirements are determined by assuming that a fire at any point will operate all the systems in every draft-curtained area that is wholly or partially within a 75-ft (22.5-m) radius of that point measured horizontally.

3-2.5.1.4 In aircraft storage and servicing areas having a maximum roof or ceiling height in excess of 75 ft (22.5 m) above the floor level, the water supply shall be sufficient for the operation of the largest number of systems. Sufficient water supply requirements are determined by assuming that a fire at any point will operate all the systems in every draft-curtained area that is wholly or partially within a 100-ft (30-m) radius of that point measured horizontally.

3-2.5.2 The water supply shall be capable of maintaining water discharge at the design rate and pressure for a minimum of 60 minutes covering the entire area protected by systems expected to operate simultaneously as determined by 3-2.5.1 of this section, unless protection is provided as specified in 3-2.5.3 of this section.

3-2.5.3 Where foam-water systems are installed, and where applicable additional protection is installed in accordance with Section 3-3 of this standard, the water supply duration shall be for a minimum of 45 minutes.

3-2.5.4 The water supply shall be capable of satisfying the requirements of Section 3-4 of this chapter for interior hose stations. The calculated demand shall be the demand at a point where supply piping for the interior hose station(s) connects to the system piping or fire protection underground.

3-2.5.5 Where the water supply for the system also serves as a supply for exterior hose streams, a hose stream allowance of 500 gpm (1893 L/min) shall be included in the water supply hydraulic calculations. Calculations for hose streams shall be in accordance with NFPA 13, *Standard for the Installation of Sprinkler Systems*.

3-2.5.6* Where a single reservoir is used for the basic water supply, such reservoir shall be divided into approximately equal sections, arranged so at least one-half of the water supply will always be maintained in service in order to increase the reliability of the water supply. The suction line from each section shall be sized to deliver the maximum water supply requirement.

3-2.6 Fire Pumps.

3-2.6.1 Fire pumps shall be installed in accordance with NFPA 20, *Standard for the Installation of Centrifugal Fire Pumps*, and in accordance with the provisions of 3-2.6.2 through 3-2.6.6.

3-2.6.2 The total pumping capacity shall be such that maximum demand can be met with the largest fire pump out of service.

3-2.6.3 Pump houses and rooms shall be of fire-resistive or noncombustible construction. Where internal combustion engines used for driving fire pumps are located inside the fire pump house or room, protection shall be provided by automatic sprinklers installed in accordance with NFPA 13, *Standard for the Installation of Sprinkler Systems*.

3-2.6.4* Fire pumps shall be started automatically by either a drop in water pressure or a signal from the detection control panel. Where two or more electrically driven fire pumps supplied from the same electrical feeder are used, they shall be electrically controlled to prevent simultaneous starting.

3-2.6.5 Frequent operation of fire pumps shall be avoided by the installation of a small auxiliary pressure maintenance pump or other suitable means to maintain normal system pressures.

3-2.6.6 Once started, fire pumps shall be arranged to run continuously until they are stopped manually. There shall be an audible “pump running” alarm in a continuously attended area.

3-2.7* Flushing Underground Pipe.

Underground mains and each lead-in connection shall be flushed as specified in NFPA 15, *Standard for Water Spray Fixed Systems for Fire Protection*.

3-2.8 Acceptance Tests.

3-2.8.1 The following tests shall be performed prior to final acceptance of any fire protection system in an aircraft hangar.

3-2.8.1.1 Hydrostatic pressure tests shall be conducted on each sprinkler system as specified in NFPA 13, *Standard for the Installation of Sprinkler Systems*, or NFPA 16, *Standard for the Installation of Deluge Foam-Water Sprinkler and Foam-Water Spray Systems*, as applicable.

3-2.8.1.2 Full-flowing tests with water only shall be made on each foam-water deluge system as a means of checking the sprinkler distribution and to ensure against clogging of piping and sprinklers by foreign matter carried by the water. The maximum number of systems that possibly could be expected to operate in case of fire, including supplementary systems, shall be in full operation simultaneously to provide a check on the adequacy and condition of the water supply. Suitable gauge connections and gauges shall be provided to verify hydraulic calculations.

3-2.8.1.3 The smallest single foam-water deluge system shall be discharged using foam concentrate. This test shall be run for a length of time sufficient to stabilize discharge before test samples are taken to determine foam concentrate percentage.

3-2.8.1.4 The maximum number of systems expected to operate shall be simultaneously discharged with foam. This test shall be run for a length of time sufficient to stabilize discharge before test samples are taken to determine foam concentrate percentage.

3-2.8.1.5 Any proportioner not tested under the requirements of 3-2.8.1.3 or 3-2.8.1.4 shall be individually tested with foam concentrate to determine concentrate percentage.

3-2.9 Final Approval.

The installing company shall furnish a written statement that the work has been completed in accordance with 3-2.1 of this section, and tested in accordance with the provisions of 3-2.8 of this section.

3-2.10 Conversion of Existing System.

In converting one type of system to another, all provisions of this chapter pertaining to new systems shall apply.

3-2.10.1 If water supplies are greater than necessary, the uniform discharge requirement of 3-2.2.6 of this section shall be permitted to be waived if the required minimum discharge rate in gal per min per sq ft is available in all areas.

3-2.10.2 Where existing systems are designed with a discharge density higher than the minimum required discharge density [0.16 gpm/ft^2 (6.5 L/min/m^2)], a proportionate reduction in the time of discharge shall be permitted but shall not be less than 7 minutes.

3-2.10.3 Converted systems shall be tested in accordance with 3-2.8 of this section.

3-2.11 Detection System Design.

3-2.11.1 Detectors for actuating the primary protection systems shall be rate-of-rise, fixed temperature, or rate compensation types.

3-2.11.2 Detection systems shall be provided with complete supervision.

3-2.11.3* Manual actuation stations shall be located so that each system can be individually operated from both inside and outside the aircraft storage and servicing area. The manual stations shall be installed so that they are unobstructed, readily accessible, and located in the normal paths of exit from the area.

3-3 Supplementary Protection Systems.

3-3.1*

Hangars housing aircraft having wing areas in excess of 3,000 ft^2 (279 m^2) shall be protected with a listed supplementary protection system.

3-3.2*

Each system shall be designed to cover a specified floor area beneath the aircraft being protected. The design objective shall be to achieve control of the fire within the protected area within 30 seconds of system actuation and extinguishment of the fire within 60 seconds.

3-3.3

Each supplemental protection system shall be designed, installed, and maintained in accordance with NFPA 11, *Standard for Low-Expansion Foam*, or NFPA 11A, *Standard for Medium- and High-Expansion Foam Systems*.

3-3.4 Plans and Specifications.

3-3.4.1* Before systems are installed, complete specifications and working plans shall be drawn to scale showing all essential details, and the plans shall be easily reproducible to provide necessary copies.

3-3.4.2* These plans and specifications shall include:

(a) Accurate and complete layout of the area to be protected, including drainage trench layout;

(b) Information on the primary protection systems installed in the hangar;

(c) Location and spacing of agent distributors, showing the area coverage;

(d) Installation layout of the actuation systems;

(e) Detailed layout of water supply piping, agent storage, pumping and piping, power sources, and location and details of mechanical foam-liquid concentrate injection equipment; and

(f) Make and type of discharge devices and foam concentrate and hydraulic calculations of the systems.

3-3.5 Low-Expansion Foam Systems.

3-3.5.1 Low-expansion foam systems shall employ AFFF, protein, or fluoroprotein foam-liquid concentrates and shall be designed for local application.

3-3.5.2* Coverage of the specified floor area beneath the aircraft shall be by means of a horizontal foam discharge from nozzles located above floor level.

3-3.5.3* Where oscillating nozzles are used, the discharge pattern limits shall be established for the design. Positive securement of the limits of oscillation shall be provided by such devices as set screws, locking pins, or similar methods. When placed in service, the manual override feature, if any, shall be locked out to provide for automatic operation only.

3-3.5.4 Where protein- or fluoroprotein-based concentrates are used, the minimum application density shall be 0.16 gpm of foam solution per sq ft (6.5 L/min/m^2) of floor area beneath the wing and wing center section of the aircraft. Where AFFF concentrate is used, the minimum application density shall be 0.10 gpm of foam solution per sq ft (4.1 L/min/m^2) of floor area beneath the wing and wing center section of the aircraft.

3-3.5.5* The quantity of foam liquid concentrate shall be sufficient for a 10-minute discharge at the water flow rate based on the supply calculation method required in 3-2.2.4.

3-3.5.6 If any nozzles are removed to allow movement of the aircraft, removal of the nozzles shall not reduce the effectiveness of the remaining system.

3-3.5.7 Electric power reliability for concentrate pumps and oscillating nozzles shall be in accordance with electric fire pump requirements of NFPA 20, *Standard for the Installation of Centrifugal Fire Pumps*.

3-3.5.8 Where monitor-type nozzles are used, an individual manual control valve shall be provided for each unit. This valve shall be supervised.

3-3.6 High-Expansion Foam Systems.

3-3.6.1 High-expansion foam systems shall utilize surfactants as the foaming ingredient and shall be designed for local application.

3-3.6.2* These systems shall be designed to discharge at a rate to cover the protected area to a depth of at least 3 ft (0.9 m) within 1 minute.

3-3.6.3 Discharge rates shall take into consideration the sprinkler breakdown factor required in 2-3.5.2(b) of NFPA 11A, *Standard for Medium-and High-Expansion Foam Systems*.

3-3.6.4* The quantity of foam concentrate shall be sufficient for a 12-minute discharge at the water flow rate based on the supply calculation method required in 3-2.2.4.

3-3.6.5 The foam generators shall be located at the ceiling or on exterior walls in such a way that only air from outside the aircraft storage and servicing area can be used for foam generation. Roof vents shall be located to avoid recirculation of combustion products into the air inlets of the foam generators.

3-3.6.6* Generators shall be powered by reliable water-driven or electric motors. Electric power reliability for both generators and concentrate pumps shall be in accordance with electric fire pump requirements of NFPA 20, *Standard for the Installation of Centrifugal Fire Pumps*.

3-3.7* Water Supply.

Water shall be available in sufficient quantity and pressure to supply the maximum number of agent distributors likely to operate simultaneously, in addition to meeting the demands of overhead hangar protection systems as determined in this chapter, and the requirements for hose stream and other equipment as determined in Section 3-4 of this chapter. Water shall be suitable for the production of foam.

3-3.8* Foam Concentrate.

3-3.8.1 The quantities of foam concentrate shall be sufficient to provide protection specified by the requirements of this chapter.

3-3.8.2* A reserve supply of foam concentrate of compatible type for the system shall be directly connected to the system and readily available. The reserve supply shall be in the same quantity as the main supply.

3-3.8.3 Where foam concentrate is introduced into the water stream by pumping, the total foam concentrate pumping capacity shall be such that the maximum pressures and flows can be met with the largest foam concentrate pump out of service.

3-3.8.4 Control valves, foam concentrate liquid storage tanks, concentrate pumps, controllers, and bypass balancing equipment shall be located outside the aircraft storage and service area.

3-3.9 Acceptance Tests.

3-3.9.1 The following tests shall be performed prior to final acceptance of any supplementary system in an aircraft hangar.

3-3.9.2 All piping shall be subjected to a 2-hour hydrostatic pressure test at 200 psi (1380 kPa) or 50 psi (345 kPa) in excess of the maximum pressure anticipated, whichever is greater, in general conformity with NFPA 13, *Standard for the Installation of Sprinkler Systems*. All normally dry piping shall be checked for leakage, freedom from obstructions, and to determine if proper drainage pitch has been provided.

3-3.9.3 All devices and equipment installed as part of the system shall be tested.

3-3.9.4 Supplementary protection systems shall be subjected to flow tests, with foam flowing simultaneously from the maximum number of primary protection systems expected to operate, in order to ensure that the hazard is protected in conformance with the design specification and to determine whether the flow pressures, agent discharge capacity, foam coverage, percent concentration, and other operating characteristics are satisfactory.

Exception: Where separate proportioning systems are utilized for the primary and supplementary protection systems, water only shall be permitted to be flowed in the primary protection system simultaneously with foam in the supplementary protection system.

3-3.9.5 Supplementary protection systems shall be examined visually to determine that they have been properly installed. Checks shall be made for such items in conformity with installation plans, continuity of piping, tightness of fittings, removal of temporary blank flanges, and accessibility of valves and controls. Devices shall be properly identified and operating instructions prominently posted.

3-3.10 Final Approval.

The installing company shall furnish a written statement to the effect that the work has been completed in accordance with approved plans and specifications, and tested in accordance with 3-3.9 of this section.

3-3.11 Actuation System.

3-3.11.1* Actuation of any primary fire protection system shall simultaneously operate the supplementary extinguishing system.

3-3.11.2 Actuation systems shall be provided with complete circuit supervision and shall be arranged in accordance with Section 3-6 of this chapter.

3-3.11.3 Manual actuation stations shall be provided for each supplemental protection system and shall be located both inside and outside the aircraft maintenance and servicing area. Stations shall be located as close as possible to the aircraft positions to facilitate early system actuation in the event of a fire.

3-4 Hand Hose Systems.

3-4.1*

Hand hose systems shall be installed in every hangar, including sprinklered hangars, to provide for manual fire control.

3-4.2

The hand hose systems shall be arranged to permit application of water or other extinguishing agents on each side and into the interior of the aircraft located in each aircraft storage and servicing area. At least two hose lines shall be considered to be operated simultaneously.

3-4.3 Foam-Water Hand Hose Systems.

3-4.3.1 Foam-water hand hose systems shall be installed in aircraft storage and servicing areas.

Exception: Where aircraft storage and servicing areas house only unfueled aircraft, as defined in 1-3.18, hand hose systems shall be provided in accordance with 3-4.4 of this standard.

3-4.3.2 The systems shall conform with the applicable portions of NFPA 14, *Standard for the Installation of Standpipe and Hose Systems*, and NFPA 11, *Standard for Low-Expansion Foam*.

3-4.3.3 These hand hose systems shall be supplied from a connection to the sprinkler system header or from a direct connection to the water source.

3-4.3.4 Each hand hose connection shall be a minimum of $1^1/_2$ in. (38 mm) in size and fitted with a control valve. The hose shall be of suitable length and diameter to provide a minimum flow of 60 gpm (227 L/min) at an adequate nozzle pressure. The stream range shall be calculated based on the volume and pressures available under maximum demand conditions.

3-4.3.5 The hose shall be properly racked or reeled. Hoses shall be fitted with an approved foam-maker nozzle or a combination-type nozzle designed to permit foam application or water spray. Nozzles shall be of the shutoff type or shall have a shutoff valve at the nozzle inlet.

3-4.3.6 Foam-liquid concentrate can be supplied from a central distribution system, separate from or a part of a foam-water sprinkler system, or from stationary foam-liquid concentrate containers fitted with listed proportioning devices.

3-4.3.7 The minimum supply of foam-liquid concentrate shall be sufficient to provide operation of at least two hand hose lines for a period of 20 minutes at a foam solution discharge rate of 60 gpm (227 L/min) each.

3-4.4 Water Hand Hose Systems.

3-4.4.1 Water hand hose and standpipe systems shall be installed in accordance with NFPA 14, *Standard for the Installation of Standpipe and Hose Systems*, in all shop, office, and nonaircraft storage areas in hangars, except where special hazards that require special protection exist.

3-4.4.2 Hoses shall be fitted with listed adjustable stream pattern nozzles designed to permit straight stream or water spray application.

3-5 Wheeled and Portable Extinguishers.

3-5.1

Wheeled and portable extinguishers shall be provided in accordance with NFPA 10, *Standard* *for Portable Fire Extinguishers*.

3-5.2

In aircraft storage and servicing areas, the distribution of such devices shall be in accordance with the extra hazard classification outlined in NFPA 10, *Standard for Portable Fire Extinguishers*.

3-5.3

The distribution of extinguishers in other areas of aircraft hangars shall be in accordance with light, ordinary, or extra hazard occupancy based on an analysis of each such room or area following the requirements of NFPA 10, *Standard for Portable Fire Extinguishers*.

3-6* Protection System Alarms.

In addition to local alarm service, alarms shall be transmitted to a constantly attended location.

Chapter 4 Protection of Group II Aircraft Hangars

4-1 General.

4-1.1

The protection of aircraft storage and servicing areas of Group II aircraft hangars, other than those housing unfueled aircraft, shall be in accordance with any one of the following:

(a) The provisions of Chapter 3 of this standard.

Exception: Where foam-water deluge systems utilizing air-aspirating discharge devices are installed for the protection of Group II aircraft hangars, the discharge rate specified in 3-2.2.12 of this standard shall be permitted to be reduced to a minimum of 0.16 gal of foam solution per min per sq ft (6.5 L/min/m^2) of floor area.

(b) A combination of automatic sprinkler protection in accordance with Section 4-2 of this chapter AND an automatic, low-level, low-expansion foam system in accordance with Sections 4-3 and 4-4 of this chapter.

(c) A combination of automatic sprinkler protection in accordance with Section 4-2 of this chapter AND an automatic high expansion foam system in accordance with Sections 4-3 and 4-5 of this chapter.

(d) A closed-head foam-water sprinkler system in accordance with Section 4-6.

4-1.2

Group II aircraft hangar storage and service areas housing unfueled aircraft shall be provided with automatic sprinkler protection specified in Sections 4-2 and 4-8.

4-1.3

Automatic closed-head sprinkler protection shall be provided inside separate shop, office, and storage areas located inside aircraft maintenance and servicing areas. The design shall be in accordance with hazard classifications specified in NFPA 13, *Standard for the Installation of Sprinkler Systems*.

4-1.4

In addition to the provision for sprinkler and foam extinguishing systems as required by this chapter, protection as required by Sections 3-4, 3-5, and 3-6 of this standard also shall be provided.

4-2 Closed-Head Water Sprinkler System for Aircraft Storage and Servicing Areas.

4-2.1*

Sprinkler systems shall be either wet pipe or preaction, designed and installed in accordance with the applicable sections of NFPA 13, *Standard for the Installation of Sprinkler Systems*, and the provisions of this chapter.

4-2.2

Sprinkler piping shall be hydraulically sized in accordance with NFPA 13, *Standard for the Installation of Sprinkler Systems*.

4-2.3

Sprinkler spacing shall be as specified in 3-2.2.3 of this standard.

4-2.4

Where open hangar doors result in interference with the distribution of water from the hangar sprinkler systems, additional sprinklers shall be provided to ensure effective floor coverage.

4-2.5

The design density from sprinkler systems shall be a minimum of 0.17 gpm of water per sq ft (6.9 L/min/m^2) over any 5,000-ft^2 (464.5-m^2) area, including the hydraulically most demanding area as defined in NFPA 13, *Standard for the Installation of Sprinkler Systems*.

4-2.6

Sprinklers shall have a nominal orifice size of $^1/_2$ in. (12.7 mm) or $^{17}/_{32}$ in. (13.5 mm).

4-2.7

Sprinklers shall have a temperature rating of 325°F to 375°F (162°C to 190°C).

4-2.8

Sprinkler systems shall be flushed and tested in accordance with NFPA 13, *Standard for the Installation of Sprinkler Systems*.

4-3* Foam Concentrate — General.

4-3.1

The foam concentrate supplied with the system shall be listed for use with the distribution equipment.

4-3.2

There shall be a reserve of foam concentrate of a compatible type directly connected to the system. The reserve supply shall be in the same quantity as the main supply.

To prevent accidental depletion of this reserve supply, it shall be available to the system only by intentional manual operation.

4-3.3 Foam Concentrate Pumps.

4-3.3.1 Where foam-liquid concentrate is introduced into the water stream by pumping, the total foam concentrate pumping capacity shall be such that the maximum flows and pressures can be met with the largest foam concentrate pump out of service.

4-3.3.2 Power supply for the drivers of foam concentrate pumps shall be installed in accordance with NFPA 20, *Standard for the Installation of Centrifugal Fire Pumps*, and NFPA 70, *National Electrical Code.*

Power supplies shall be arranged such that disconnecting power to the protected facility during a fire shall not disconnect the power supply to the foam concentrate pump feeder circuit.

4-3.3.3 Controllers for foam concentrate pumps shall be as follows:

(a) For electric drive foam concentrate pumps greater than 30 horsepower, a listed fire pump controller shall be used.

(b) For electric drive foam concentrate pumps greater than 15 horsepower but not exceeding 30 horsepower, a listed fire pump controller or listed limited service controller shall be used.

(c) For electric drive foam concentrate pumps less than 15 horsepower, a listed limited service controller shall be used.

(d) For diesel engine drive foam concentrate pumps, a listed fire pump controller shall be used.

4-3.3.4 Piping shall be arranged so that maximum foam concentrate demand can be supplied from either primary or reserve foam concentrate tanks.

4-3.4

The control valves, foam-liquid concentrate storage, injection system, and foam concentrate pump shall be located outside aircraft storage and servicing areas. The environmental conditions shall be suitable for the particular agent involved.

4-3.5

Plans and specifications for closed-head foam-water sprinkler systems shall provide the information required by 3-2.1.2 of this standard and NFPA 16A, *Standard for the Installation of Closed-Head Foam-Water Sprinkler Systems*. Plans and specifications for other foam extinguishing systems shall provide the information required by 3-3.4 of this standard.

4-3.6 Acceptance Tests.

4-3.6.1 Acceptance tests for closed-head foam-water sprinkler systems shall be performed in accordance with NFPA 16A, *Standard for the Installation of Closed-Head Foam-Water Sprinkler Systems*.

4-3.6.2 Acceptance tests for foam extinguishing systems shall be performed in accordance with 3-3.9.2, 3-3.9.3, and 3-3.9.5 of this standard.

4-3.6.2.1 The systems shall be subjected to flow tests with foam flowing from the maximum number of foam distributors expected to operate in order to ensure that the hangar is protected in conformance with the design specifications, and to determine if the flow pressures, agent discharge capacity, foam coverage, percentage of concentration, and other operating characteristics are satisfactory.

4-3.6.2.1.1 A flow test shall be performed with only the foam system operating.

4-3.6.2.1.2 A flow test shall be performed with the foam system operating at the design pressure with the sprinkler system and hose demand.

4-3.7

The installing company shall furnish a written statement to the effect that the work has been completed in accordance with approved plans and specifications, and tested in accordance with the provisions of 4-3.6 of this section.

4-4* Low-Expansion Foam System.

4-4.1

Foam systems shall be of the fixed type and shall be designed and installed in accordance with the requirements for fixed-type systems in NFPA 11, *Standard for Low-Expansion Foam*.

4-4.2

The minimum application rate shall be 0.16 gpm of foam solution per sq ft (6.5 L/min/m^2) where protein-based or fluoroprotein-based concentrate is used. Where AFFF concentrate is used, the minimum application rate shall be 0.10 gpm of foam solution per ft^2 (4.1 L/min/m^2).

4-4.3*

The discharge rate of the system shall be based on the rate of application multiplied by the entire aircraft storage and servicing floor area.

4-4.4

The foam system shall use low-level monitor-type discharge nozzles, with individual manual shutoff valves for each nozzle.

The discharge nozzles shall be arranged to achieve initial foam coverage in the expected aircraft parking area.

4-4.5*

The quantity of foam concentrate shall be sufficient for a 10-minute discharge at the water flow rate based on the supply calculation method.

4-5 High-Expansion Foam System.

4-5.1

High-expansion foam systems shall be designed and installed in accordance with NFPA 11A, *Standard for Medium- and High-Expansion Foam Systems*, requirements for local application systems.

4-5.2

The high-expansion foam generators shall be arranged to achieve initial foam coverage in the anticipated aircraft parking area.

4-5.3

The effective application rate shall be a minimum of 3 cfm/ft^2 (0.0014 m^3/s).

4-5.4

The discharge rate of the system shall be based on the application rate multiplied by the entire aircraft storage and servicing floor area. The application total discharge rate shall include the sprinkler breakdown factor specified in 2-3.5.2(b) of NFPA 11A, *Standard for Medium- and High-Expansion Foam Systems*.

4-5.5

Foam generators shall be supplied with air from outside the aircraft storage and servicing area. Roof vents shall be located to avoid recirculation of combustion products into the air inlets of the foam generators.

4-5.6

Foam generators shall be powered by reliable water-driven or electric motors. Electric power reliability for both foam generators and foam concentrate pumps shall be consistent with electric fire pump requirements specified in Chapters 6 and 7 of NFPA 20, *Standard for the Installation of Centrifugal Fire Pumps*.

4-5.7

The quantity of foam concentrate shall be sufficient to operate the system at the required discharge rate as determined in 4-5.4 for a period of at least 12 minutes.

4-6 Closed-Head Foam-Water Sprinkler System.

4-6.1

Closed-head foam-water sprinkler systems shall be designed and installed in accordance with NFPA 16A, *Closed-Head Foam-Water Sprinkler Systems*.

4-6.1.1 AFFF shall be used.

4-6.2

The minimum discharge density shall be 0.16 gpm/ft^2 (6.5 L/min/m^2) of foam solution over the entire storage and service area.

4-6.3

Sprinkler spacing shall not exceed 100 ft^2 (9.3 m^2) as projected on the floor. The maximum distance between sprinklers either on branch lines or between branch lines shall be 12 ft (3.6 m).

4-6.4

In aircraft storage and servicing areas, the maximum projected floor area under an individual sprinkler system shall not exceed 15,000 ft^2 (1393 m^2).

4-6.4.1 Each individual system shall have its own foam concentrate proportioner.

4-6.5

Sprinklers shall have a temperature rating of 175°F to 225°F (79.4°C to 107.2°C).

4-6.6

Foam concentrate supply shall be in accordance with 3-2.3 of this standard.

4-6.7*

Branch lines shall be provided with provisions for periodic flushing.

4-6.7.1 Drains shall be a minimum of 1 in. (2.5 cm) in size.

4-7 Detection and Actuation Systems.

4-7.1

Detectors for actuating high- or low-expansion foam systems and for actuating preaction sprinkler systems shall be rate-of-rise, fixed temperature, or rate compensation type.

4-7.2

These detectors shall be installed in accordance with NFPA 72, *National Fire Alarm Code*.

4-7.3

Detection systems shall be provided with supervision as required by NFPA 72, *National Fire Alarm Code*.

4-7.4

Manual actuation stations shall be located so that each system can be individually operated from both inside and outside the aircraft storage and servicing area. The manual stations shall be installed so that they are unobstructed, readily accessible, and located in the normal paths of exit from the area.

4-8* Water Supply.

4-8.1

The total water supply shall be sufficient to satisfy the combination of systems and hose stations as described in 4-1.1(b), 4-1.1(c), and 4-1.3 of this chapter for durations as specified in this section.

4-8.2

The water supply for closed-head water sprinkler systems in aircraft storage and servicing areas shall meet one of the following:

(a) In aircraft storage and servicing areas housing other than unfueled aircraft, the water supply shall have a minimum duration of 30 minutes at the rate specified in 4-2.5.

(b) In aircraft storage and servicing areas housing unfueled aircraft, the water supply shall have a minimum duration of 60 minutes at the rate specified in 4-2.5.

4-8.3

The water supply for low-expansion foam systems shall be capable of furnishing water at the rate specified in 4-4.2 of this chapter for a period of time at least equal to twice the period of time used to calculate the quantity of foam liquid concentrate in 4-4.5. Water shall be suitable for the production of foam.

4-8.4

The water supply for high-expansion foam systems shall be capable of furnishing water at the rate specified in 4-5.3 of this chapter for a minimum period of 24 minutes. Water shall be suitable for the production of foam.

4-8.5

The water supply for closed-head foam-water sprinkler systems shall have a minimum duration of 30 minutes at the rate specified in 4-6.2.

4-8.6

The water supply for hose stations shall be capable of satisfying the requirements of Section 3-4 of this standard, in addition to those requirements specified in 4-8.2 and either 4-8.3 or 4-8.4 of this section. The demand shall be calculated at the point where supply piping for the hose stations connects to the system piping or fire protection underground.

4-8.7

Where the water supply for the systems also serves as a supply for exterior hose streams, a hose stream allowance of 500 gpm (1893 L/min) shall be included in the water supply hydraulic calculations. Calculations for hose stream shall be in accordance with NFPA 13, *Standard for the Installation of Sprinkler Systems*.

4-8.8

Where provided, fire pumps and suction reservoirs shall be designed and installed in accordance with 3-2.5.6 and 3-2.6 of this standard.

Chapter 5 Group III Aircraft Hangars

5-1 Construction.

5-1.1*

Group III hangars shall be constructed of any of the types of construction specified in NFPA 220, *Standard on Types of Building Construction*.

5-1.2

Group III hangars shall be limited to one story. Where a Group III hangar as defined in 1-3.2.3 exceeds one story, the hangar shall be designated as a Group II hangar.

5-1.3

The surface of the grade floor of aircraft storage and servicing areas, regardless of type of hangar construction, shall be noncombustible and above the grade of the approach or apron at the entrance to the hangar.

5-1.4

Hangar aprons shall slope away from the level of the hangar floors to prevent liquid on the apron surfaces from flowing into the hangars.

5-1.5

In freestanding hangars for a single aircraft and in row hangars, a minimum of 6-in. (15-cm) high curbing shall be provided between each aircraft space to prevent the flow of liquid from one space to adjacent spaces.

Open-bay hangars capable of housing multiple aircraft shall be provided with floor drainage in accordance with Section 2-11 of this standard.

5-1.6

Roof coverings shall be listed as Class C, or better, where tested in accordance with NFPA 256, *Standard Methods of Fire Tests of Roof Coverings*.

5-1.7

Exposed interior insulation attached to walls and roofs in aircraft storage and servicing areas shall be noncombustible as defined in NFPA 220, *Standard on Types of Building Construction*.

In an aircraft storage and servicing area of a hangar equipped with an approved sprinkler system designed in accordance with Chapter 4 of this standard, exposed interior insulation attached to walls and roofs shall be permitted to be limited noncombustible as defined in NFPA 220, *Standard Types of Building Construction*.

5-2 Separation and Internal Subdivisions.

5-2.1

For single hangar buildings, the clear space distances specified in Table 5-2.1 shall be maintained on all sides of the single hangar. Where mixed types of construction are involved, the less fire-resistant type of construction shall be used to determine clear space required. Where the minimum clear spaces specified in Table 5-2.1 are not met, the buildings shall be considered a hangar building cluster.

Table 5-2.1

Type of Construction	Minimum Separation Required
Type I (443) and (332)	50 ft (15 m)
Type II (222)	50 ft (15 m)
Type II (111), Type III (211), and Type IV (2HH)	50 ft (15 m)
Type II (000)	50 ft (15 m)
Type III (200)	50 ft (15 m)
Type V (111) and (000)	75 ft (23 m)

Where single hangar buildings adjoin each other and each has fire walls with a minimum rating of at least 2 hours, located so that fire areas shall not exceed the maximum areas specified in Table 1-3.2.3 of this standard, no minimum separation distance shall be required. These buildings shall not be considered a hangar building cluster.

5-2.2

Row hangars shall be divided by solid partitions having a fire resistance equivalent to that of the exterior walls or roof, whichever is greater, so that no more than three aircraft spaces shall be within an enclosed area.

5-2.3

Partitions and ceilings separating aircraft storage and servicing areas from other areas, such as shops, offices, and parts storage areas, shall have at least a 1-hour fire resistance rating with openings protected by listed fire doors having a fire resistance rating of at least $^{3}/_{4}$ hour.

5-3 Hangar Building Clusters.

5-3.1

In hangar building clusters, Group III hangars within that cluster shall be limited in total area for the specific types of construction in accordance with Table 5-3.1. Where mixed types of construction are involved, the less fire-resistant type of construction shall be used to determine the maximum allowable area in accordance with the table.

Table 5-3.1 Maximum Fire Areas for Hangar Building Clusters

Types of Construction	Hangar Building Clusters (Ft^2)	(M^2)
Type I (443) and (332)	60,000	(5,574)
Type II (222)	40,000	(3,716)
Type II (111), Type III (211), and Type IV (2HH)	30,000	(2,787)
Type II (000)	24,000	(2,230)
Type III (200)	24,000	(2,230)
Type V (111)	16,000	(1,486)
Type V (000)	10,000	(929)

5-3.2

Where the total area of all Group III hangars in a cluster exceeds that specified in Table 5-3.1, selected buildings in the hangar cluster shall be considered as Group II hangars and protected in accordance with Chapter 4 of this standard. These buildings shall be selected such that the total area of the unprotected Group III hangar buildings in the hangar cluster is below the maximum area allowed by Table 5-3.1 for the less fire-resistant type of construction.

5-3.3

For hangar building clusters, the clear space distances specified in Table 5-3.3 shall be maintained on all sides of the hangar building clusters. Where mixed types of construction are involved, less fire-resistant type of construction shall be used.

Table 5-3.3

Type of Construction	Minumum Separation Required
Type I (433) and (332)	75 ft (23 m)
Type II (222)	75 ft (23 m)

Type IV (2HH)	75 ft (23 m)
Type II (111) and Type III (211)	100 ft (30 m)
Type II (000)	100 ft (30 m)
Type III (200)	100 ft (30 m)
Type V (111) and (000)	125 ft (38 m)

5-4 Heating and Ventilating.

5-4.1

Heating, ventilation, and air conditioning equipment shall be installed, as applicable, in accordance with NFPA 90A, *Standard for the Installation of Air Conditioning and Ventilating Systems*; NFPA 31, *Standard for the Installation of Oil-Burning Equipment*; and NFPA 54, *National Fuel Gas Code*, except as hereinafter specifically provided.

5-4.2

No heating, ventilation, and air conditioning equipment employing an open flame or glowing element shall be installed in aircraft storage and servicing areas or sections communicating therewith, except as provided for in 5-4.5 of this section.

5-4.3

Hangar heating plants that are fired with gas, liquid, or solid fuels not covered under 5-4.5 of this section, and that are not located in a detached building, shall be located in a room separated from other parts of the hangar by construction having at least a 1-hour fire resistance rating. This separated room shall not be used for any other hazardous purpose or combustible storage and shall have no direct access from the aircraft storage or servicing area. Openings in the walls of such rooms communicating with other portions of the hangar shall be restricted to those necessary for ducts or pipes. Penetrations of the 1-hour fire resistance rated enclosure shall be firestopped with an approved material properly installed and capable of maintaining the required fire resistance rating for the enclosure. Each such duct shall be protected with a listed automatic fire damper or door. All air for combustion purposes entering such separated rooms shall be drawn from outside the building.

5-4.4*

Heating, ventilating, and air conditioning plants employing recirculation of air within aircraft storage and servicing areas shall have return air openings not less than 10 ft (3 m) above the floor. Supply air openings shall not be installed in the floor and shall be at least 6 in. (152 mm) from the floor measured to the bottom of the opening.

Where automatic fire protection systems are installed in aircraft storage and servicing areas, fans for furnace heating systems shall be arranged to shut down automatically by means of the operations of the interior automatic fire protection system. One or more manual fan shutoff switches shall be provided. Shutoff switches shall be accessible and clearly placarded.

5-4.5 Suspended or Elevated Heaters.

5-4.5.1 Listed electric, gas, or oil heaters shall be permitted to be used if installed as specified in 5-4.5.2, 5-4.5.3, and 5-4.5.4 of this subsection.

5-4.5.2 In aircraft storage and servicing areas, heaters shall be installed at least 10 ft (3 m) above the upper surface of wings or of the engine enclosures of the highest aircraft that can be housed in the hangar. The measurement shall be made from the wing or engine enclosure, whichever is higher from the floor, to the bottom of the heater.

5-4.5.3 In shops, offices, and other sections of aircraft hangars communicating with aircraft storage or servicing areas, the bottom of the heaters shall be installed not less than 8 ft (2.4 m) above the floor.

5-4.5.4 Suspended or elevated heaters shall be located in all spaces of aircraft hangars so that they shall not be subject to injury by aircraft, cranes, movable scaffolding, or other objects. Provision shall be made to ensure accessibility to suspended heaters for recurrent maintenance purposes.

5-4.6

Where a mechanical ventilating system is employed in hangars or shops, the ventilating system shall be installed in accordance with NFPA 90A, *Standard for the Installation of Air Conditioning and Ventilating Systems*, and in accordance with the applicable provisions of Section 5-4 of this chapter.

5-4.7

Where blower and exhaust systems are installed for vapor removal, the systems shall be installed in accordance with NFPA 91, *Standard for Exhaust Systems for Air Conveying of Materials*.

5-5 Lighting and Electrical Systems.

5-5.1

Artificial lighting shall be restricted to electric lighting.

5-5.2*

Electrical services shall be installed in compliance with the provisions for aircraft hangars contained in Article 513 of NFPA 70, *National Electrical Code*.

5-6 Lightning Protection.

Where provided, lightning protection shall be installed in accordance with NFPA 780, *Standard for the Installation of Lightning Protection Systems*.

5-7 Grounding Facilities for Static Electricity.

5-7.1*

Grounding facilities shall be provided for removal and control of static electrical accumulations on aircraft while aircraft are stored or are undergoing servicing in a hangar.

5-7.2

An adequate number of floor-grounding receptacles shall be provided. The receptacles shall be either grounded through individual driven electrodes or electrically bonded together in a grid system and the entire system grounded to underground metal piping or driven electrodes. Where driven electrodes are used, they shall consist of $^5/_8$ in. (15.9 mm) diameter or larger metal rods driven at least 5 ft (1.5 m) into the ground. Floor grounding receptacles shall be designed to minimize the tripping hazard.

5-7.3*

Grounding wires shall be bare and of a gauge that will be satisfactorily durable to withstand mechanical strains and usage.

5-8 Exit and Access Requirements.

5-8.1

Means of egress from the aircraft hangar shall comply with NFPA *101*, *Life Safety Code*.

Egress doors for personnel that do not require the opening of doors accommodating aircraft shall be provided in each partitioned space. Intervals between doors shall not exceed 150 ft (45 m) on all exterior walls or 100 ft (30 m) along interior walls.

5-8.2

Aisles and clear space shall be maintained to ensure access to sprinkler control valves, where provided, standpipe hose, fire extinguishers, and similar equipment.

5-9 Fire Protection for Group III Hangars.

5-9.1

Where hazardous operations including fuel transfer, welding, torch cutting, torch soldering, doping, and spray painting are performed in any Group III hangar, the Group III hangar shall be protected with the fire protection specified in Chapter 4 of this standard and also shall meet the requirements specified in 2-4.2 of this standard.

5-9.2

Portable fire extinguishers shall be provided in accordance with NFPA 10, *Standard for Portable Fire Extinguishers*. Where portable extinguishers are locked up to preclude the possibility of theft, each tenant and aircraft owner shall be provided with a key for the locks.

5-9.2.1 In aircraft storage and servicing areas, the distribution of portable fire extinguishers shall be in accordance with extra hazard classification outlined in NFPA 10, *Standard for Portable Fire Extinguishers*.

5-9.2.2 The distribution of extinguishers in other areas of aircraft hangars shall be in accordance with light, ordinary, or extra hazard occupancy based on an analysis of each room or area following the requirements of NFPA 10, *Standard for Portable Fire Extinguishers*.

Chapter 6 Periodic Inspection and Testing

6-1 Fire Protection Systems.

6-1.1

Inspection and testing of fire protection systems in aircraft hangars shall be performed in accordance with Table 6-1.1.

Table 6-1.1

System Components	Weekly	Monthly	Semi- Ann.	Ann.	Qtrly.	5 Yrs.
	Type and Frequency of Inspection and Tests					
Sprinkler Heads				V		
Piping				V		D
Pipe Hangers				V		
Sprinkler Alarm Valve		V			01	
Deluge Valve		V		O		D
Shutoff Valves		V		F		
Fire Pumps	F4			D		
Water Reservoirs		V				
Hose Stations		V				D
Strainers				V		
Foam Concentrate				F2		
Conc. Storage Tanks		V				
Conc. Pump	F4			O		D
Conc. Control Valve (Auto)		V		O		D
Conc. Shutoff Valve		V		F		
Foam Prop. Device		V				D
H_2O Powered Mon. Noz.		V		D		
Elec. Powered Man. Noz.		V		F		D
H_2O Powered HEF Gen.		V		O		D
Elec. Powered HEF Gen.		V		F		D
Pneumatic Detector			F	O3		
Electric Detector			F	O3		
Optical Detector	V		F	O3		
Control Panels		V	F	O		
Alarm Transmission (Local & Remote)		F				
Tamper Switch					F	
Flow Indication Switch				O		

Supervisory Alarms		F		
Manual Actuation Stations		F		
Hangar Floor Drain Sys. & Separators	V			D
Fire Doors	V		F	
Gas Detectors	V	F		
Ventilation System in Pits, Tunnels, & Ducts		F		
Grounding Equipment				F

V = Visual
F = Functional (No flow)
O = Operational (W/Flow - No Discharge)
D = Operational with actual discharge

1 = For the purposes of this test, the inspector's flow valve is acceptable.
2 = A sample should be sent to the manufacturer for analysis.
3 = At this time it is necessary to check that the set points are the same as the original.
4 = Churn test.

6-1.2

All preprimed closed-head AFFF systems shall be drained, flushed, and reprimed annually.

6-1.3

Records of inspections, tests, and test results shall be maintained.

Chapter 7 Referenced Publications

7-1

The following documents or portions thereof are referenced within this standard and shall be considered part of the requirements of this document. The edition indicated for each reference is the current edition as of the date of the NFPA issuance of this document.

7-1.1 NFPA Publications.

National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.

NFPA 10, *Standard for Portable Fire Extinguishers*, 1994 edition.

NFPA 11, *Standard for Low-Expansion Foam*, 1994 edition.

NFPA 11A, *Standard for Medium- and High-Expansion Foam Systems*, 1994 edition.

NFPA 13, *Standard for the Installation of Sprinkler Systems*, 1994 edition.

NFPA 14, *Standard for the Installation of Standpipe and Hose Systems*, 1993 edition.

NFPA 15, *Standard for Water Spray Fixed Systems for Fire Protection*, 1990 edition.

NFPA 16, *Standard for the Installation of Deluge Foam-Water Sprinkler and Foam-Water Spray Systems*, 1995 edition.

NFPA 16A, *Standard for the Installation of Closed-Head Foam-Water Sprinkler Systems*, 1994 edition.

NFPA 20, *Standard for the Installation of Centrifugal Fire Pumps*, 1993 edition.

NFPA 31, *Standard for the Installation of Oil-Burning Equipment*, 1992 edition.

NFPA 54, *National Fuel Gas Code*, 1992 edition.

NFPA 58, *Standard for the Storage and Handling of Liquefied Petroleum Gases*, 1995 edition.

NFPA 69, *Standard on Explosion Prevention Systems*, 1992 edition.

NFPA 70, *National Electrical Code*, 1996 edition.

NFPA 72, *National Fire Alarm Code*, 1993 edition.

NFPA 90A, *Standard for the Installation of Air Conditioning and Ventilating Systems*, 1993 edition.

NFPA 90B, *Standard for the Installation of Warm Air Heating and Air Conditioning Systems*, 1993 edition.

NFPA 91, *Standard for Exhaust Systems for Air Conveying of Materials*, 1995 edition.

NFPA *101*, *Life Safety Code*, 1994 edition.

NFPA 220, *Standard on Types of Building Construction*, 1995 edition.

NFPA 256, *Standard Methods of Fire Tests of Roof Coverings*, 1993 edition.

NFPA 415, *Standard on Aircraft Fueling Ramp Drainage*, 1992 edition.

NFPA 780, *Standard for the Installation of Lightning Protection Systems*, 1995 edition.

Appendix A Explanatory Material

This Appendix is not a part of the requirements of this NFPA document but is included for informational purposes only.

A-1-2.1

The adequacy and usefulness of aircraft hangars depends to a large extent on the fire resistance of their construction and the fire protection provided within the buildings.

A-1-3 Group III Aircraft Hangars.

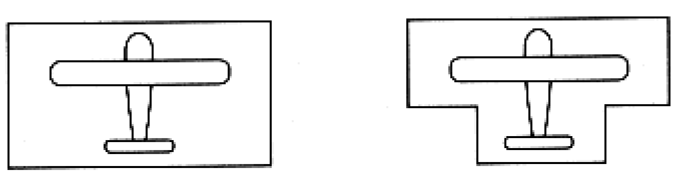


Figure A-1-3(a) Freestanding unit for single aircraft.

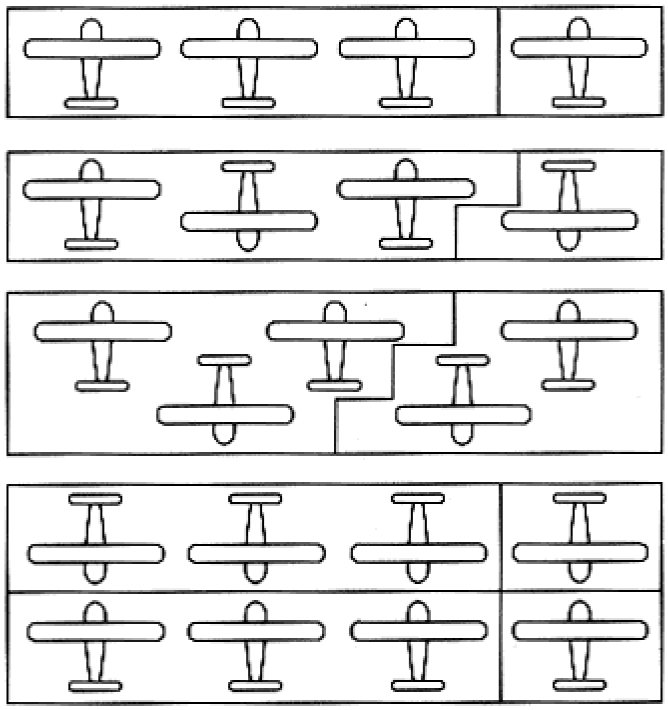


Figure A-1-3(b) Typical configurations of row hangars.

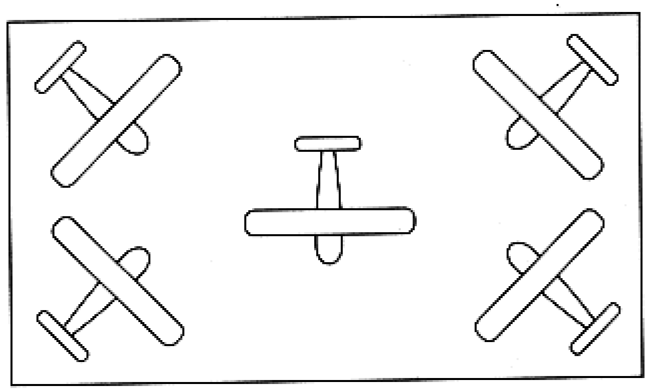


Figure A-1-3(c) Hangar capable of housing multiple aircraft.

A-1-3 Approved.

The National Fire Protection Association does not approve, inspect, or certify any installations, procedures, equipment, or materials; nor does it approve or evaluate testing laboratories. In determining the acceptability of installations, procedures, equipment, or materials, the authority having jurisdiction may base acceptance on compliance with NFPA or other appropriate standards. In the absence of such standards, said authority may require evidence of proper installation, procedure, or use. The authority having jurisdiction may also refer to the listings or labeling practices of an organization concerned with product evaluations that is in a position to determine compliance with appropriate standards for the current production of listed items.

A-1-3 Authority Having Jurisdiction.

The phrase "authority having jurisdiction" is used in NFPA documents in a broad manner, since jurisdictions and approval agencies vary, as do their responsibilities. Where public safety is primary, the authority having jurisdiction may be a federal, state, local, or other regional department or individual such as a fire chief; fire marshal; chief of a fire prevention bureau, labor department, or health department; building official; electrical inspector; or others having statutory authority. For insurance purposes, an insurance inspection department, rating bureau, or other insurance company representative may be the authority having jurisdiction. In many circumstances, the property owner or his or her designated agent assumes the role of the authority having jurisdiction; at government installations, the commanding officer or departmental official may be the authority having jurisdiction.

A-1-3 Listed.

The means for identifying listed equipment may vary for each organization concerned with product evaluation, some of which do not recognize equipment as listed unless it is also labeled. The authority having jurisdiction should utilize the system employed by the listing organization to identify a listed product.

A-2-1.1

Building construction types are defined in NFPA 220, *Standard on Types of Building Construction*. The following material is extracted verbatim from the 1992 edition of NFPA 220, and is included here as a convenience for users of this standard. Any requests for Formal Interpretations (FI) or Tentative Interim Amendments (TIA) on the following material must be directed to the Technical Committee on Building Construction.

3-1 Type I (443-332). Type I construction is that type in which the structural members, including walls, columns, beams, floors, and roofs, are of approved noncombustible or limited-combustible materials and have fire resistance ratings not less than those set forth in Table 3.

3-2 Type II (222-111-000). Type II construction is that type not qualifying as Type I construction in which the structural members, including walls, columns, beams, floors, and roofs, are of approved noncombustible or limited-combustible materials and have fire resistance ratings not less than those set forth in Table 3.

3-3 Type III (211-200). Type III construction is that type in which exterior walls and structural members that are portions of exterior walls are of approved noncombustible or limited-combustible materials, and interior structural members, including walls, columns, beams, floors, and roofs, are wholly or partly of wood of smaller dimensions than required for Type IV construction or of approved noncombustible, limited-combustible, or other approved combustible materials. In addition, structural members have fire resistance ratings not less than those set forth in Table 3.

3-4 Type IV (2HH).[1]

1The dimensions used for sawn and glued laminated lumber in this section are nominal dimensions.

3-4.1 Type IV construction is that type in which exterior and interior walls and structural members that are portions of such walls are of approved noncombustible or limited-combustible materials. Other interior structural members, including columns, beams, arches, floors, and roofs, are of solid or laminated wood without concealed spaces and comply with the provisions of 3-4.2 through 3-4.6. In addition, structural members have fire resistance ratings not less than those set forth in Table 3.

Exception No. 1: Interior columns, arches, beams, girders, and trusses of approved materials other than wood shall be permitted provided they are protected to provide a fire resistance rating of not less than 1 hour.

Exception No. 2: Certain concealed spaces shall be permitted by the Exception to 3-4.4.

3-4.2 Wood columns supporting floor loads shall be not less than 8 in. (203 mm) in any dimension; wood columns supporting roof loads only shall be not less than 6 in. (152 mm) in least dimension and not less than 8 in. (203 mm) in depth.

3-4.3 Wood beams and girders supporting floor loads shall be not less than 6 in. (152 mm) in width and not less than 10 in. (254 mm) in depth; wood beams and girders and other roof framing, supporting roof loads only, shall be not less than 4 in. (102 mm) in width and not less than 6 in. (152 mm) in depth.

3-4.4 Framed or glued laminated arches that spring from grade or the floor line and timber trusses that support floor loads shall be not less than 8 in. (203 mm) in width or depth. Framed or glued laminated arches for roof construction that spring from grade or the floor line and do not support floor loads shall have members not less than 6 in. (152 mm) in width and not less than 8 in. (203 mm) in depth for the lower half of the height and not less than 6 in. (152 mm) in depth for the upper half. Framed or glued laminated arches for roof construction that spring from the top of walls or wall abutments and timber trusses that do not support floor loads shall have members not less than 4 in. (102 mm) in width and not less than 6 in. (152 mm) in depth.

Exception: Spaced members shall be permitted to be composed of two or more pieces not less than 3 in. (76 mm) in thickness when blocked solidly throughout their intervening spaces or when such spaces are tightly closed by a continuous wood cover plate not less than 2 in. (51 mm) in thickness, secured to the underside of the members.

Splice plates shall be not less than 3 in. (76 mm) in thickness.

3-4.5 Floors shall be constructed of splined or tongued and grooved plank not less than 3 in. (76 mm) in thickness covered with 1-in. (25-mm) tongue and groove flooring, laid crosswise or diagonally to the plank, or with 1/2-in. (12.7-mm) plywood, or of laminated planks not less than 4 in. (102 mm) in width, set on edge close together, spiked at intervals of 18 in. (457 mm) and covered with 1-in. (25-mm) tongue and groove flooring laid crosswise or diagonally to the plank or with 1/2-in. (12.7-mm) plywood.

3-4.6 Roof decks shall be of splined or tongued and grooved plank not less than 2 in. (51 mm) in thickness; or of laminated planks not less than 3 in. (76 mm) in width, set on edge close together, and laid as required for floors; or of 11/8-in. (28.6-mm) thick interior plywood (exterior glue); or of approved noncombustible or limited-combustible materials of equal fire durability.

3-5 Type V (111-000). Type V construction is that type in which exterior walls, bearing walls, and floors and roofs and their supports are wholly or partly of wood or other approved combustible material smaller than required for Type IV construction. In addition, structural members have fire resistance ratings not less than those set forth in Table 3.

Table 3 Fire Resistance Requirements for Type I through Type V Construction

	Type I		Type II		
	443	332	222	111	000
Exterior Bearing Walls –					
Supporting more than one floor, columns, or other bearing walls......	4	3	2	1	0[1]
Supporting one floor only....................	4	3	2	1	0[1]
Supporting a roof only.........................	4	3	1	1	0[1]
Interior Bearing Walls –					
Supporting more than one floor, columns, or other bearing walls......	4	3	2	1	0
Supporting one floor only....................	3	2	2	1	0
Supporting roofs only..........................	3	2	1	1	0
Columns –					
Supporting more than one floor, columns, or other bearing walls......	4	3	2	1	0
Supporting one floor only....................	3	2	2	1	0
Supporting roofs only..........................	3	2	1	1	0
Beams, Girders, Trusses & Arches –					
Supporting more than one floor, columns, or other bearing walls......	4	3	2	1	0
Supporting one floor only....................	3	2	2	1	0
Supporting roofs only..........................	3	2	1	1	0
Floor Construction	3	2	2	1	0
Roof Construction	2	1 1/2	1	1	0
Exterior Nonbearing Walls	0[1]	0[1]	0[1]	0[1]	0[1]

Those members that shall be permitted to be of approved combustible material.

[1] See NFPA 220, A-3-1 (Table).

[2] "H" indicates heavy timber members; see NFPA 220 for requirements.

A-2-1.2

Preference should be given to the use of noncombustible materials in Type V (111) and (000) hangars. Separate shops, offices, and storage areas should comply with the provisions of 2-2.1.

A-2-2.1

Fire wall construction should be in accordance with a listed construction assembly or the local building code. The construction should be resistant to or protected from mechanical damage and potential damage from discharge of the fixed fire protection system.

Possible reasons to subdivide aircraft storage and service areas into separate fire areas include:

(a) Reducing required water supplies.

(b) Reducing exposed values for insurance or other purposes.

(c) Reducing exposure between occupants.

(d) Modifying the hangar classification.

A-2-2.3

Shops, office, and storage areas should be in separate, detached buildings. Workshops, offices, and storage areas having their own roof coverings and built within aircraft storage or servicing areas should have watertight roof deck coverings.

A-2-3.2.3 See also NFPA 80, *Standard for Fire Doors and Fire Windows*.

A-2-3.3.2 See also NFPA 80, *Standard for Fire Doors and Fire Windows*.

A-2-4.2

These special hazards include, but are not limited to, spray painting or doping areas, flammable liquid storage or mixing rooms, etc.

A-2-5.3

Construction types will dictate the need for sprinkler protection in these spaces.

A-2-6.3

Additional guidance pertaining to fixed water systems can be found in NFPA 15, *Standard for Water Spray Fixed Systems for Fire Protection*. This information can also be used in the design of foam-water systems. The design of such protection should take into account factors such as the shape of the column, wetting of lower sprinklers, etc.

A-2-7.3

Preplanning should ensure availability of necessary auxiliary equipment such as tractors, cables, grapnels, etc., where manual operation is either impossible or too slow to allow prompt aircraft removal.

A-2-9.1

Landing gear pits, ducts, and tunnels located beneath the hangar floor should be avoided if possible because of the danger of accumulation of flammable liquids or vapors; where their use is essential, the protection measures specified in Section 2-9 must be followed. For floor drainage, see 2-11.2.

A-2-9.7

The venting arrangements will depend on the design of the pits, elevating platforms, and means of access. It might be necessary for part of the platform surface to be grated or perforated to provide adequate explosion venting area. The general principles in NFPA 68, *Guide for Venting of Deflagrations*, should be followed.

A-2-9.8

Consideration should be given to the selection of an extinguishing agent that could also be used as a means of inerting the pit in the event that flammable vapors are present concurrent with the loss of use of the ventilation system due to power failure, maintenance, or other causes.

A-2-11.2.2 Aircraft hangars also might require floor drainage systems to effectively dispose of water used for cleaning aircraft and hangar floor surfaces and water accumulation from possible flooding due to high groundwater tables, and to drain away water discharged from the fire protection equipment provided within the structure. Reference can be made to NFPA 415, *Standard on Aircraft Fueling Ramp Drainage*, for information on drainage systems and the appendix of NFPA 15, *Standard for Water Spray Fixed Systems for Fire Protection*, for information on drainage equipment and arrangements.

A-2-11.2.4 In general, this will mean that the design must be adequate to ensure that the liquid level at the center of the drain is below the top surface of the drain inlet grating for grated round, rectangular, and long trench-type inlets, or the floor surface in the case of a slit trench.

A-2-12.1

It is recommended that hangar heating, ventilating and air conditioning equipment fired with gas, liquid, or solid fuel be located in a fire-resistive or noncombustible detached building wherever possible.

A-2-12.4

Personnel should be fully instructed that in the event of a serious gasoline or similar flammable liquid spill on the hangar floor, the fans should be shut off.

A-2-13.2

See also 2-7.2 for power supply to doors accommodating aircraft.

A-2-14

All aircraft hangars should be surveyed to determine the need for approved lightning protection. Where installed, such systems should be listed. See NFPA 780, *Standard for the Installation of Lightning Protection Systems*.

A-2-15.1

As low a resistance as possible should be secured and maintained. Ten thousand ohms is a practical recommended maximum where determined by standard procedures. For further details on this subject, see NFPA 407, *Standard for Aircraft Fuel Servicing*, and NFPA 77, *Recommended Practice on Static Electricity*.

A-2-15.3

Speedometer, preformed steel, or equivalent cable will minimize danger of employee hand injury.

A-2-17 Draft Stops.

(a) *Depth.* Draft stops should extend down from the roof or ceiling of aircraft storage and servicing areas not less than one-eighth of the height from the floor to roof or ceiling. Under curved or sloping roofs extending to grade level or close to grade level, draft stops need not be continued below 16 ft (4.8 m) from the floor.

(b) *Installation.* Draft stops should be installed, preferably at right angles to the hangar doors, forming roof pockets that are rectangular in shape. Hangars that are long and narrow, however, might best be subdivided by a "grid" system of draft stops that are both at right angles and parallel to the doors. In arch-type hangars, draft stops can be hung on exposed interior roof supports running parallel to the doors. The method of installation should be based on obtaining maximum operational efficiency from the sprinkler protection, taking into consideration mean wind conditions, floor drains, floor pitch, and details of occupancy usage.

(c) *Roof Sections as Draft Stops.* Structural features of a building that serve the purpose of draft stops (such as roof monitors, sawtooth roofs, etc.) may be permitted in lieu of specially constructed draft stops.

A-3-2.1.1 It is highly important and expedient that all applicable areas of responsibility, such as those that cover adequacy of water supplies, design, testing, flushing, approvals, etc., be clearly defined in the contract documents. This is important where there is shared responsibility for various portions of the fire protection systems.

A-3-2.2.2 The manual control valve for each individual sprinkler system should be located outside aircraft storage and servicing areas.

A-3-2.3 See A-3-3.8.

A-3-2.4.1 Reliability of power supplies for drivers of water pumps, foam concentrate pumps, and foam generators will be a function of all the facilities between the pump driver and the power source. For a diesel engine driven pump and an electric motor driven pump, the independence of the power sources is very clear. This, of course, assumes there is a battery powered starter for the diesel engine. Independence of two diesel engines with separate fuel tanks is also fairly easily seen.

However, the degree of independence of the power sources for two electric motor drivers is much more difficult to establish. A single controller, a single switchgear cabinet, or a single cable route might easily negate the desired reliability.

The considerations of power supply reliability are required in various sections of NFPA 20, *Standard for the Installation of Centrifugal Fire Pumps*, and NFPA 16, *Standard for the Installation of Deluge Foam-Water Sprinkler and Foam-Water Spray Systems*. These considerations should demonstrate that the power supply reliability is consistent with that achieved for the mechanical components. There are a number of methods available. Such a method could be a simple inspection and statement of design philosophy or a sophisticated fault tree analysis.

A-3-2.5.1 Actual flow rates are often higher than calculated. This will often result in a reduction in foam supply duration.

Aircraft storage and servicing areas with large doors on both ends can present special draft problems affecting the efficient operation of the sprinkler systems. In such cases, additional systems should be included in the calculation of water supply needed. Draft stops should effectively surround each individual sprinkler system. (*See Section 2-17*.)

A-3-2.5.6 The development of satisfactory water supplies is a matter requiring engineering judgment and careful analysis of local conditions. See NFPA 419, *Guide for Master Planning Airport Water Supply Systems for Fire Protection*; NFPA 20, *Standard for the Installation of Centrifugal Fire Pumps*; and NFPA 22, *Standard for Water Tanks for Private Fire Protection*. Acceptable types of water supplies can consist of one or more of the following:

(a) Connections to reliable waterworks systems, including automatic booster pumps where required;

(b) Automatic fire pumps taking suction under a head from storage reservoirs or other suitable supply; and

(c) Gravity tanks.

Combinations of these supplies can be used to advantage. It is desirable to have two independent water supplies. Where reliance is placed on automatic fire pumps, special consideration should be given to the use of multiple pumps rather than single pumps and the use of multiple sources of power in order to increase the reliability of pump drivers. Water supplies should be guarded against entry of foreign material that would clog sprinklers or piping. Waterworks connections, where used as an independent supply, should be capable of delivering water at the specified rate and pressure as determined by flow tests, with due consideration given to any conditions that could have an effect on the design supply and pressure. Investigation should be made to determine the normal and emergency operation of the waterworks system, including domestic consumption and operation of the waterworks pumps at time of test, pressure-reducing valves, or other factors affecting adequacy of a public water supply. Automatic booster fire pumps should be used to provide effective pressure from waterworks connections.

A-3-2.6.4 Supplemental means for automatically starting the fire pumps should also be provided.

A-3-2.7

In connection with the flushing operation, preplanning should be made for means of disposing of the large quantities of water discharged.

A-3-2.11.3 In locating manual actuation stations inside, multiple stations should be considered to provide occupants with a selection of paths of exit from which they can actuate the system.

The location of exterior actuation stations should ensure accessibility once the occupant has exited the hangar through any of the emergency exits. Security fences, adjacent buildings, or other obstructions should be considered when locating exterior actuation stations.

A-3-3.1

Supplementary protection systems for hangars containing several aircraft, each having wing areas less than 3,000 ft^2 (279 m^2), can be warranted. Such systems are recommended where:

(a) Rapid control of a fuel fire exposing a single aircraft is considered essential.

(b) Strategically important military aircraft or multiple high valued aircraft are accommodated.

(c) Arrangement of aircraft within a hangar results in congestion and limited access to individual aircraft.

Table A-3-3.1

Following is a listing of the wing areas of various transport-type aircraft:

Wing Areas of Various Aircraft

		Wing Area	
	Aircraft	**Ft^2**	**(M^2)**
1*	L-500-Galaxy	6,200	(576.0)
2*	Boeing 747	5,500	(511.0)
3*	Concorde	3,856	(358.2)
4*	DC-10-20, 30	3,550	(329.8)
5*	L-1011	3,456	(321.1)
6*	Boeing 767	3,050	(283.4)
7*	Ilyushun IL-62	3,030	(281.5)
8	Boeing 707-320 B/C	2,950	(274.1)
9	DC-10	2,932	(272.4)
10	DC-8-63	2,927	(271.9)
11	DC-8-62	2,926	(271.8)
12	DC-8-61	2,883	(267.8)
13	A-300 Airbus	2,799	(260.0)
14	BAC-3-11	2,450	(227.6)
15	A310 Airbus	2,357	(218.9)
16	Tupolev TU-154	2,169	(201.5)
17	Boeing 757	1,951	(181.2)
18	L-100-20 Hercules	1,745	(162.1)
19	Caravelle	1,579	(146.7)
20	Boeing 727-100	1,560	(144.9)
21	Trident 3B	1,493	(138.7)
22	Trident 1E	1,466	(136.2)
23	Tupolev TU-34	1,370	(127.3)
24	Trident 1C	1,358	(126.2)

25	BAC 1-11-500	1,031	(95.8)
26	NAMC YS-11	1,020	(94.8)
27	BAC 1-11-300,400	1,003	(93.2)
28	DC 9-30	1,001	(93.0)
29	Boeing 737-200, 300	980	(91.0)
30	DC 9-20	934	(86.8)
31	Convair 640	920	(84.5)
32	Herald	886	(82.3)
33	Fokker Fellowship	822	(76.4)
34	Fokker Fellowship	754	(70.0)
35	Nord	592	(55.0)
36	Twin Otter	420	(39.0)
37	Beechcraft Model 99	298	(27.7)

*Aircraft with wing areas in excess of 3,000 ft^2 (279 m^2)

A-3-3.2

In general, the specified floor area would be the area under the wing and wing center sections of the aircraft. Configuration of aircraft and positioning of aircraft and ground equipment within an aircraft storage and servicing area can compromise the effectiveness of any supple mental protection systems. Original design and testing of such systems should anticipate obstructions on the floor (such as those created by working platforms) in providing protection over the specified floor areas. The discharge from overhead hangar protection systems might not protect the aircraft from a fire in the shielded areas beneath the wing and wing center section. The supplementary system is intended to provide protection in these shielded areas by controlling such fires quickly and preventing extensive damage to the aircraft. The area to be protected depends on the configuration and the number of aircraft and their positioning arrangements, as well as the location of permanent service structures within the aircraft maintenance and servicing area. Protection of the entire aircraft maintenance and servicing area could be required because of the variety of possible aircraft positioning arrangements.

The total area to be protected by a single system depends on the number and configuration of aircraft and their proximity to one another and the drainage arrangements. If more than one aircraft is located within any drainage system, the supplementary foam system should preferably be capable of covering the floor area beneath all such aircraft.

A-3-3.4.1 It is highly important and expedient that all applicable areas of responsibility, such as those that cover suitability of agent, application rates used, area covered, approvals, testing, etc., be clearly defined in the contract documents. This is especially important where there might be shared responsibility for the various portions of the fire protection system.

A-3-3.4.2,**A-3-3.5.2** The total area to be protected by a single system depends on the number and configuration of aircraft and their proximity to one another and the drainage arrangements. If more than one aircraft is located within any drainage system, the supplementary foam system should preferably be capable of covering the floor area beneath all such aircraft.

A-3-3.5.3 Experience has shown that the mechanism for manual operation of automatic oscillating monitor nozzles is a major factor in the failure rate of these devices. A large percentage of these failures has been due to operators failing to change the device from the manual to the automatic mode after testing, maintenance, etc. It is considered that the most reliable device is one that is designed for automatic operation only and that has no manual operating mode.

A-3-3.5.5 Actual flow rates are often higher than calculated. This will often result in a reduction in foam supply duration.

A-3-3.6.2 To achieve the design principles, the rate of foam rise should be at least 3 ft/min (0.9 m/min) beneath the aircraft wings and wing center section. With large shielded areas, a higher rate of foam rise could be required. The foam generators should be installed and positioned in such a way that the flow of foam on the floor is directed to areas beneath the aircraft wings and wing center section. If the fire spreads to the aircraft interior, it could seriously damage or destroy the aircraft unless an automatic fire extinguishing system is also provided inside the aircraft cabin. If generators are located on the exterior of the hangar, the possible hazards of freezing water on the generator screens should be considered. The discharge of high-expansion foam in the hangar space can handicap visibility for manual fire fighting.

A-3-3.6.4 Actual flow rates are often higher than calculated. This will often result in a reduction in foam supply duration.

A-3-3.6.6 See A-3-2.4.1.

A-3-3.7

The presence of corrosion inhibitors, antifreeze agents, marine growth, oil, or other contaminants can result in the reduction of foam volume or stability. If the quality of the water used is questionable, the manufacturer of foam equipment should be consulted. In general, the performance of a foam-water extinguishing system depends on the agent composition, the proportioning concentration, and the application technique. Different brands or types of agents should not be mixed without the advice of the equipment manufacturer regarding their interchangeability and compatibility.

A-3-3.8

Experience has shown that different brands of foam might not be compatible and may have varying levels of fire-fighting effectiveness. Care should be utilized in the selection of foam concentrates.

A-3-3.8.2 To prevent accidental use and depletion of this reserve supply, it should be available to the system only by intentional manual operation.

A-3-3.11.1 Detection systems for supplementary systems should be either a radiation (infrared or ultraviolet) or a heat responsive (continuous strip-type or thermistor-type) system. When initially installed, if there is any doubt as to the stability of these actuating devices because of environmental factors, it is recommended that the devices be utilized to actuate only an alarm rather than trigger the extinguishing systems. As soon as operational experience indicates that the devices are stable, they should be arranged to automatically actuate the extinguishing equipment. Spacing of detection devices should be no greater than the maximum recommended by the manufacturer.

A-3-4.1

Section 3-4 provides a means for fire fighting by occupants of the hangar through the use of hand hose supplied from the hangar's fixed fire protection system or from an independent source. The hand hose system in aircraft storage and servicing areas is usually arranged for foam application with water spray or straight water streams used in other areas.

A-3-6

For further information, see NFPA 72, *National Fire Alarm Code*.

A-4-2.1

A preaction standard sprinkler system should be used only if there is a possibility of freezing in an unheated hangar.

A-4-3, A-4-4 See A-3-3.8.

A-4-4.3

This design criteria can be achieved by means of multiple nozzles of the same or different capacities aimed to discharge toward the aircraft parking area. The fluidity of the foam will achieve coverage of the entire floor area.

A-4-4.5

Actual flow rates are often higher than calculated. This will often result in a reduction in foam supply duration.

A-4-6.7

This should be accomplished by providing manifolded drains.

A-4-8

See A-3-3.7.

A-5-1.1

Group III hangars for small aircraft are either prefabricated assemblies or are locally constructed of unprotected steel or aluminum, light wood framing, or cement or cinder blocks. The majority of the prefabricated types are unprotected steel structures with sheet steel or aluminum roof coverings and sidings. Other prefabricated hangars have wood or cement sidings and wood or plywood doors. Except in unusual circumstances, construction types other than Type II (000) and Type V (000) are unlikely because of cost factors. Earth floors are common. Floor drainage is not required for single unit or row hangars, although utility drains are useful and should be provided. The airport operator should have a master key for the Group III hangars on the airport premises so as to provide emergency access in case of fire. (*See A-2-1.1.*)

A-5-4.4

Personnel should be fully instructed that in the event of a serious gasoline or similar flammable liquid spill on the hangar floor, the fans should be shut off.

A-5-5.2

See also 2-7.2 for power supply to doors accommodating aircraft.

A-5-7.1

As low a resistance as possible should be secured and maintained. Ten thousand ohms is a practical recommended maximum where determined by standard procedures. For further details on this subject, see NFPA 407, *Standard for Aircraft Fuel Servicing*, and NFPA 77, *Recommended Practice on Static Electricity*.

A-5-7.3

Speedometer, preformed steel, or equivalent cable should minimize danger of employee hand injury.

Appendix B Referenced Publications

B-1

The following documents or portions thereof are referenced within this standard for informational purposes only and thus should not be considered part of the requirements of this document. The edition indicated for each reference is the current edition as of the date of the NFPA issuance of this document.

B-1.1 NFPA Publications.

National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.

NFPA 15, *Standard for Water Spray Fixed Systems for Fire Protection*, 1990 edition.

NFPA 16, *Standard for the Installation of Deluge Foam-Water Sprinkler and Foam-Water Spray Systems*, 1995 edition.

NFPA 20, *Standard for the Installation of Centrifugal Fire Pumps*, 1993 edition.

NFPA 22, *Standard for Water Tanks for Private Fire Protection*, 1993 edition.

NFPA 68, *Guide for Venting of Deflagrations*, 1994 edition.

NFPA 72, *National Fire Alarm Code*, 1993 edition.

NFPA 77, *Recommended Practice on Static Electricity*, 1993 edition.

NFPA 80, *Standard for Fire Doors and Fire Windows*, 1995 edition.

NFPA 220, *Standard on Types of Building Construction*, 1995 edition.

NFPA 407, *Standard for Aircraft Fuel Servicing*, 1990 edition.

NFPA 415, *Standard on Aircraft Fueling Ramp Drainage*, 1992 edition.

NFPA 419, *Guide for Master Planning Airport Water Supply Systems for Fire Protection*, 1992 edition.

NFPA 780, *Standard for the Installation of Lightning Protection Systems*, 1995 edition.

NFPA 410

1994 Edition

Standard on Aircraft Maintenance

1994 Edition

This edition of NFPA 410, *Standard on Aircraft Maintenance*, was prepared by the Technical Committee on Aircraft Maintenance Operations and acted on by the National Fire Protection Association, Inc., at its Annual Meeting held May 16 - 18, 1994, in San Francisco, CA. It was issued by the Standards Council on July 14, 1994, with an effective date of August 5, 1994, and supersedes all previous editions.

The 1994 edition of this document has been approved by the American National Standards Institute.

Origin and Development of NFPA 410

Work on an overall project to develop recommendations on fire safety safeguards for aircraft maintenance was launched in 1955. NFPA 410A, *Recommendations on Safeguarding Aircraft Electrical System Maintenance Operations*, was adopted in 1958; NFPA 410B, *Recommendations on Aircraft Breathing Oxygen Systems Maintenance Operations*, was adopted in 1958; NFPA 410C, *Recommendations on Safeguarding Aircraft Fuel System Maintenance*, was adopted in 1962; NFPA 410D, *Recommendations for Safeguarding of Aircraft Cleaning, Painting, and Paint Removal*, was adopted in 1965; NFPA 410E, *Recommended Safe Practice for Aircraft Welding Operations in Hangars*, was adopted in 1963; and NFPA 410F, *Recommendations on Safeguarding Aircraft Cabin Cleaning and Refurbishing Operations*, was adopted in 1963. The 1980 edition was a compilation of the 410 series, compiled as a standard. The 1989 edition of the standard was completely revised. A chapter was added for the fire protection of ramp areas where aircraft can be parked.

This edition is a reconfirmation of the 1989 edition.

Technical Committee on Aircraft Maintenance Operations

John R. Flynn, *Chair*
American Airlines, TX

Nathaniel J. Addleman, Boeing Comm. Airplane, KS

Joseph A. Behnke, Ansul Fire Protection, WI
Rep. Fire Equipment Manufacturer's Assn., Inc.

Jim DeWitt, Int'l Assn. of Machinists & Aerospace Workers, MO

John J. O'Sullivan, British Airways, England

Thomas M. Suehr, Wausau Insurance Co., WI
Rep. The Alliance of American Insurers

Jack A. Treasure, University of Missouri, MO

Alternates

John F. Trinajstich, Kidde-Fenwal Protection Systems, NC (Alt. to J. A. Behnke)

Nonvoting

Jerome Lederer, Laguna Hills, CA
(Member Emeritus)

Mark T. Conroy, NFPA Staff Liaison

This list represents the membership at the time the Committee was balloted on the text of this edition. Since that time, changes in the membership may have occurred.

NOTE: Membership on a Committee shall not in and of itself constitute an endorsement of the Association or any document developed by the Committee on which the member serves.

Committee Scope: This Committee shall have primary responsibility for documents for fire safe practices during maintenance operations on aircraft including similar operations on aircraft during manufacture. This scope does not include aircraft fuel servicing.

NFPA 410

Standard on Aircraft Maintenance

1994 Edition

NOTICE: An asterisk (*) following the number or letter designating a paragraph indicates explanatory material on that paragraph in Appendix A.
Information on referenced publications can be found in Chapter 9 and Appendix B.

Chapter 1 Administration

1-1 Scope.

1-1.1

This standard covers the minimum requirements for fire safety to be followed during aircraft maintenance and does not include the health and safety requirements for personnel involved in aircraft maintenance. The operations include maintenance of electrical systems, maintenance of oxygen systems, fuel tank repairing, cleaning, painting and paint removal, welding operations in hangars, interior cleaning, and refurbishing operations.

1-1.2

This standard also covers requirements for fire protection of aircraft ramp areas.

1-2 Purpose.

1-2.1

The purpose of this standard is to provide a reasonable degree of protection for life and property from fire through requirements for aircraft maintenance based upon sound engineering principles, test data, and field experience.

1-3 Definitions.

Air Ventilation. To pass undiluted air (air not containing flammable vapors or inert gases) through an aircraft tank to render the atmosphere of the tank more suitable for human occupancy and to reduce the amount of flammable vapors in the tank to below the lower explosive limit of the fuel vapors involved. It is recognized that, at some time during and possibly after air ventilation, the tank may contain a flammable vapor-air mixture. During such periods, a fire and explosion hazard exists that requires the elimination of ignition sources within the vapor-hazardous areas.

Aircraft Breathing-Oxygen System. A system onboard aircraft to provide breathing oxygen to occupants of aircraft. Such systems do not include equipment used for or with either gaseous or liquid oxygen when used for any purpose other than for breathing. Such systems do not include equipment used for the storage and handling of breathing oxygen and charging equipment outside of operations directly associated with breathing oxygen systems.

Approved. Acceptable to the authority having jurisdiction.

NOTE: The National Fire Protection Association does not approve, inspect, or certify any installations, procedures, equipment, or materials; nor does it approve or evaluate testing laboratories. In determining the acceptability of installations, procedures, equipment, or materials, the authority having jurisdiction may base acceptance on compliance with NFPA or other appropriate standards. In the absence of such standards, said authority may require evidence of proper installation, procedure, or use. The authority having jurisdiction may also refer to the listings or labeling practices of an organization concerned with product evaluations that is in a position to determine compliance with appropriate standards for the current production of listed items.

Authority Having Jurisdiction. The organization, office, or individual responsible for approving equipment, an installation, or a procedure.

NOTE: The phrase “authority having jurisdiction” is used in NFPA documents in a broad manner, since jurisdictions and approval agencies vary, as do their responsibilities. Where public safety is primary, the authority having jurisdiction may be a federal, state, local, or other regional department or individual such as a fire chief; fire marshal; chief of a fire prevention bureau, labor department, or health department; building official; electrical inspector; or others having statutory authority. For insurance purposes, an insurance inspection department, rating bureau, or other insurance company representative may be the authority having jurisdiction. In many circumstances, the property owner or his or her designated agent assumes the role of the authority having jurisdiction; at government installations, the commanding officer or departmental official may be the authority having jurisdiction.

Bladder Tanks. See Fuel Tanks, Bladder.

Cleaning, Exterior. The removal of soil from the complete aircraft exterior or from only localized areas where flammable or combustible solvents are used.

Cleaning, Interior.* The removal of soil from flight deck and cabin areas.

Coating. Application of special-purpose materials such as anticorrosion and walkway paints.

Combustible Liquids. Any liquid having a flash point at or above 100°F (38°C). Classifications are in accordance with NFPA 321, *Standard on Basic Classification of Flammable and Combustible Liquids*.

Electric Converters. Used to convert line voltage alternating current to the voltage and frequency, or direct current, suitable for the aircraft power system. Rectifier units are also used to accomplish this task.

Flammable Liquids. Any liquid having a flash point under 100°F (38°C) closed cup and having a vapor pressure not exceeding 40 psia (2068.6 mm) at 100°F (38°C).

Flight Deck. The area of the aircraft arranged for use by pilot/flight crew in operating the aircraft. Berths, galleys, and lavatory facilities can be associated with the flight crew compartment but are not included in the term “flight deck.”

Fuel Tanks, Bladder. Both collapsible and self-sealing tanks. The bladders themselves are of a special synthetic rubber and fabric material. Normally these cells have a fairly low melting point and change pliability with relatively small changes in temperature. Pliability is a critical quality in the fuel cell material. A plasticizing agent is compounded into the synthetic rubber to keep it pliable. Fuel tends to extract the plasticizing agent; however, this is not detrimental since fuel itself keeps the material pliable.

Fuel Tanks, Integral. Fuel containers whose boundaries are made up of as nearly 100 percent primary structure as possible, primary structure being the elements of the aircraft that carry the major stresses of flight, such as stressed skin spar caps, spar webs, etc. Integral fuel tanks can be part of either the wing or the fuselage. Integral fuel tanks discussed here are confined to the types that are basically without gasket materials installed in the seams, the structural cavities being made fuel-tight by the installation of a sealing material after the completion of fabrication of the unit where the tank is located.

Fuel Tanks, Metal. All types of metal fuel containers, including surge and vent tanks, that can be removed from the aircraft for shop or bench repair, but not including metal fuel containers that are an integral part of the aircraft that, under certain major overhaul conditions, can be removed from the primary portion of the airframe.

Galley. An area of an aircraft used for storing, refrigerating, heating, and dispensing of food and beverages. Such an area typically includes storage areas for plastic trays, plastic dinnerware utensils, and paper napkins.

Hot Work. Work including welding, cutting, soldering, explosive riveting, or any similar process involving an open flame, the application of heat, or a spark-producing tool.

Inert Atmosphere. An atmosphere where combustion cannot occur.

Inert Gas. Any gas that is nonflammable, chemically inactive, noncontaminating for the use intended, and oxygen deficient to the extent required.

Inerting. The use of an inert gas to render the atmosphere of an enclosure nonexplosive or nonflammable. Inerting, in effect, reduces the oxygen content of the air in the tank vapor space below the lowest point at which combustion can occur by replacing the oxygen in air with an inert gas.

Integral Tanks. See Fuel Tanks, Integral.

Listed. Equipment or materials included in a list published by an organization acceptable to the authority having jurisdiction and concerned with product evaluation that maintains periodic inspection of production of listed equipment or materials and whose listing states either that the equipment or material meets appropriate standards or has been tested and found suitable for use in a specified manner.

NOTE: The means for identifying listed equipment may vary for each organization concerned with product evaluation, some of which do not recognize equipment as listed unless it is also labeled. The authority having jurisdiction should utilize the system employed by the listing organization to identify a listed product.

Maintenance. Overhaul, repair, and service operations as herein defined.

Major Painting. Complete or virtually complete surface finishing of either the exterior or interior, or both.

May. This term is used to state a permissive use, or an alternative method to a specified requirement.

Metal Fuel Tanks. See Fuel Tanks, Metal.

Overhaul. The major disassembly, inspection, repair, and reassembly of aircraft.

Oxygen, Gaseous. Gaseous oxygen is colorless, tasteless, and nontoxic. It comprises about 21 percent of normal air by volume and is about 10 percent heavier than air. Above its critical temperature of 180.4°F (82.4°C), oxygen can exist only as a gas regardless of the pressure exerted upon it.

Paint Removal. The process of softening existing paint by application of appropriate solvents and spraying or brushing away the residue.

Purging. The removal of flammable vapor atmospheres or any residue capable of producing flammable vapors in the tank and connected distribution lines so that subsequent natural ventilation will not result in the reinstatement of a flammable atmosphere unless or until a flammable liquid is again introduced into the tank or its connected distribution lines.

Ramp. Any outdoor area at an airport, including aprons and hardstands, on which aircraft are normally fueled, defueled, stored, parked, maintained, or serviced.

Refurbishing. The types of refurbishing operations considered herein are the replacement of aircraft interior fabrics, plastic headliners, rugs or synthetic flooring, sound-insulating materials, windows, doors, or paneling.

Repair. The modification of aircraft, rebuilding structural damage, correcting system malfunction, or replacing a major component or subassembly that requires the aircraft to be in "out of flying" status.

Service Operation. Routine service checks, correction of flight crew complaints, and minor repair and maintenance performed while the aircraft is routinely in "out of flying" status.

Shall. Indicates a mandatory requirement.

Should. Indicates a recommendation or that which is advised but not required.

Tanks. See Fuel Tanks.

Touch-up Painting. The refinishing of only localized areas, exterior or interior, involving no more than 1 qt (1 L) of material by spray or 1 gal (4 L) by brush or roller.

1-4* Units.

In this standard, values for measurement are followed by an equivalent in SI units, but only the first value stated shall be regarded as the requirement. Equivalent values in SI units shall not be considered as the requirement as these values may be approximate.

Chapter 2 Electrical Maintenance Operations

2-1 General.

2-1.1

Electrical system maintenance as used herein and references to NFPA 70, *National Electrical Code*®, shall apply only to aircraft maintenance.

2-1.2

Electrical systems shall be de-energized during maintenance work except in those cases where a live circuit is necessary to accomplish the required maintenance.

2-1.3

Where more than one maintenance operation is being carried out at the same time and an electrical system is energized, steps shall be taken to inform personnel working on the aircraft that the system is energized.

2-1.4

Wherever possible, provision shall be made to effectively tag out or lock out de-energized circuits so that anyone attempting to energize them will be unmistakably alerted to the resulting hazard to other maintenance operations.

2-2 Battery Charging and Equipment.

2-2.1

Whenever possible, aircraft batteries shall be disconnected or removed during maintenance operations in order to de-energize all electrical circuits.

2-2.2

The battery switch on aircraft shall be in the “off” position before removing or installing batteries.

2-2.3*

When moving batteries, including removal and replacement, precautions shall be taken to prevent the terminal prongs from contacting metal structures or objects.

2-2.3.1 During maintenance, extension cable used to provide power to the aircraft from batteries that are not in their normally installed location shall be equipped with standard aircraft battery connectors and integral fusible overload protection. Fuses shall be the instantaneous type and sized no larger than 10 amps above the maximum connected load.

2-2.4

When removing and replacing batteries, precautions shall be taken to prevent the electrolyte from spilling. Similar precautions shall be taken when replacing or adding electrolyte solutions in batteries.

2-2.5*

Batteries in the aircraft shall only be charged where adequate on-the-ground ventilation is provided.

2-2.6

Flexible cords used for charging shall be suitable for the type of service used and approved for extra-hard usage.

2-2.7

Connectors shall have a rating not less than the current-carrying capacity of the cord.

2-2.8

Connectors to the battery terminals shall be of a positive type to prevent them from coming loose due to vibration, causing arcs that might ignite gas from the batteries or other flammables or combustibles.

2-2.9

Tables, racks, trays, and wiring shall conform to the provisions of Article 480 of NFPA 70, *National Electrical Code*, where storage batteries use acid or alkali as the electrolyte and consist of a number of cells connected in series with a nominal voltage in excess of 16 volts.

2-2.10

Mobile chargers shall carry at least one permanently affixed warning sign to read: “Warning—Keep 5 Ft (1.5 M) Horizontally Clear of Aircraft Engines, Fuel Tank Areas, and Vents.”

2-2.11*

Batteries shall be charged at a rate that will not produce a dangerous concentration of gas or excessive heat.

2-2.12

Battery manufacturer’s instructions shall be followed with regard to segregation of nickel-cadmium battery-charging operations from lead-acid battery charging operations to prevent contamination.

2-2.13

Battery chargers and their control equipment, tables, racks, trays, and wiring shall not be located or operated within any of the hazardous areas defined in 513-2(b) of NFPA 70, *National Electrical Code*. They shall preferably be located in a separate building or in an area such as described in 513-2(d) of NFPA 70.

2-2.14

Areas wherein batteries are charged shall be well ventilated to assure that the maximum gas-air mixture that may be generated during charging is held below the lower explosive limits. Where mechanical ventilation is required to accomplish this, it shall be of the type listed for use in Class 1, Group B atmosphere locations as defined in Article 500 of NFPA 70, *National Electrical Code*, and shall be so interlocked as to ensure operation when batteries are on charge. Exhaust ducts shall lead directly to the outside, above roof level, where gases cannot accumulate.

2-2.15

Access to battery rooms shall be limited to qualified personnel only.

2-2.16

Smoking shall be prohibited, and open flames, sparks, arcs, and other sources of ignition shall be kept away from the immediate vicinity of batteries that are being charged. Appropriate warning signs shall be prominently displayed.

2-2.17

Brushes used to clean batteries shall have neither a metal frame nor wire bristles.

2-3 Ground Power Units.

2-3.1

Placement of ground power units in use shall comply with the requirements of Section 513-9 of NFPA 70, *National Electrical Code*, and 2-6.2 of NFPA 407, *Standard for Aircraft Fuel Servicing*.

2-3.2

Ground power units shall be located as far as practical from fueling points, tank vents, tank outlet areas, fuel line drains, and wings. Ground power units shall not be positioned within a 25-ft (8-m) horizontal radius of aircraft fuel system vent openings. They shall not be used in areas wherein adequate ventilation is not available or where they may constitute a fire hazard.

2-3.2.1 If used inside hangars, in addition to the requirements of 2-3.3 of this section, ground power units shall also be so designed and mounted that all electrical equipment, sparking contacts, hot surfaces, and any other possible ignition source shall be at least 18 in. (457 mm) above floor level. At no time shall engine-driven generators be refueled within any aircraft maintenance or storage area within a hangar.

2-3.3

Electrical equipment in hangar floor pits used to store cables shall be of the type approved for Class I, Group D, Division 1 hazardous locations as defined by NFPA 70, *National Electrical*

Code.

2-3.4

A protection system shall be provided to protect against undervoltage and overvoltage.

2-3.5

Ground power units shall always be operated at the prescribed voltage.

2-3.6*

The battery switch in the aircraft shall be turned to the "off" or "ground power" position when the ground power unit is connected to the aircraft.

2-3.7

In the event of extensive fuel spills or whenever similar hazardous conditions exist, ground power units in the vicinity that would constitute a fire hazard shall be withdrawn or left as is until the hazardous condition is corrected. If a portable ground power unit is to be moved under such hazardous conditions, the unit shall be de-energized before disconnecting the cable, and the cable shall be disconnected before the unit is moved.

2-3.8

Cables shall be stowed properly to prevent damage.

2-3.9

Strains on cables and connectors shall be avoided.

2-3.10

The ground power units shall be turned on only after the connector is installed in the aircraft receptacle. When connected, the unit shall be checked to determine that it is operating at the prescribed voltage before supplying power to the aircraft.

2-3.11

The ground power units shall be de-energized before disconnecting, or anti-arcing provisions that interlock the load contactors with the aircraft electrical system shall be provided.

2-3.12

Portable ground power units shall be disconnected before they are moved.

2-4 Repair of Aircraft Electrical Systems.

2-4.1

Consideration shall be given to de-energizing the entire aircraft electrical system by disconnecting or removing the batteries and by disconnecting any outside power source. The use of a "dummy" ground power plug shall be considered.

2-4.2

Whenever the entire aircraft electrical system is not de-energized, all personnel working on the aircraft shall be informed that the aircraft's electrical systems are energized.

2-4.3

Whenever the entire aircraft electrical system is not de-energized due to other work being accomplished, the electrical system being worked on shall be isolated by placing the circuit breaker in an “off” position or pulling the fuse.

2-4.4

When an electrical system is to be isolated in order to work on it, the person who is going to work on the system shall place the circuit breaker in an “off” position or pull the fuse. That person shall not rely on someone else to do this. A positive test on the isolated circuit shall be made.

2-4.5

When two or more people are going to work on the same system, provisions shall be made to make one person responsible for energizing or de-energizing the system.

2-4.6

Circuit breakers shall be in the “off” position and fuses shall be pulled before removing and installing system units.

2-4.7*

The use of a “tag-out” system, covering the switch with masking tape, or some other similar method shall be used to positively indicate that an electrical system is being worked on and that it shall not be energized except on the authorization of the supervisor. (*See Figure A-2-4.7.*)

2-4.8

When working on energized electrical systems in areas containing flammable fluid lines, the following precautions shall be taken:

(a)* Precautions shall be taken whenever working on any part of the aircraft to prevent accidental contact of control cables, tools, or metal parts with energized electrical systems, components, or both. Adjacent terminals, electrical components and wiring, and flammable fluid lines shall be protected to prevent arcing and fire if accidental cross contact is made.

(b) An extinguisher having a rating of not less than 20-B and a minimum capacity of 15 lb (6.8 kg) of agent shall be located within 50 ft (15.2 m) of the work operation.

2-4.9

When troubleshooting, all wires shall be considered “hot” until proven otherwise.

2-4.10

Nonconductive or insulated tools shall be used for working on “hot” circuits.

2-4.11

The aircraft electrical circuit involved shall be de-energized whenever equipment and wiring is removed or installed.

2-4.12

Equipment that is new or repaired shall be thoroughly tested and checked for short circuit before being installed on the aircraft.

2-4.13

Aircraft wiring shall be properly secured to prevent chafing.

2-4.14

All loops provided in electrical cables to prevent flammable fluids from entering electrical connections or components shall be re-formed so that they will perform their intended functions.

2-4.15

When dripshields, cables, sheaths, plug covers, or similar devices have been provided to prevent flammable fluids from contacting electrical components, care shall be taken to see that they are reinstalled so that they effectively perform their intended function.

2-5 Repairs to Communications and Navigation Equipment.

2-5.1

Radar and radio transmitting equipment shall not be operated, tested, or checked on the aircraft whenever fueling, defueling, tank repair operations during the time when flammable vapor-air atmospheres are present, or any other similar hazardous operation is taking place within the distance limits outlined in Section 2-9 of NFPA 407, *Standard for Aircraft Fuel Servicing*, or within the distances of the manufacturer's prescribed limitations.

2-5.2

Such operation, testing, or checking may be made at any time if a dummy load, which prevents the energizing of the antenna, is used. In addition, the precautions outlined in 2-4.10 through 2-4.15 of this chapter shall be followed.

2-6 Cleaning of Electrical Components Installed on the Aircraft.

2-6.1

Electrical components shall not be energized and shall be isolated from other power sources during cleaning operations.

2-6.2

Only nonflammable solvents shall be used for cleaning electrical components.

2-7 Testing of Electrical Equipment During and Following Repair Operations.

2-7.1

Testing of electrical equipment installed on aircraft shall be held to a minimum. Whenever possible, testing shall be done at a bench or in a shop away from the aircraft.

2-7.2

Equipment shall be checked for continuity of circuitry and resistance before power is applied.

2-8 Energizing and De-energizing Electric Circuits During Complete Engine Change.

2-8.1

Standard aircraft static-grounding procedures shall be followed.

2-8.2

Magneto circuits shall be grounded when disconnected at the fire wall.

2-8.3

The electrical systems involved in an engine installation shall be de-energized prior to removal of the engine and remain de-energized until any hazard of flammable vapors in the area has been removed.

2-8.4

Pertinent electrical systems shall be de-energized prior to installation of the engine and remain de-energized until all flammable fluid system connections are completed and no flammable vapors exist in the area.

2-8.5

Personnel performing an engine change shall be advised when the electrical systems are de-energized and re-energized following the principles expressed in 2-1.4 and 2-4.5 of this chapter.

2-8.6

The de-energized circuits shall be tagged out or locked out so that persons attempting to energize them will be definitely aware that others could be endangered by their action.

2-8.7

Electrical disconnects shall be protected against accidental contact, dirt, and moisture during the disconnect period, by tight-fitting blind plugs, tape wrapping, or both.

2-9 Electrical Equipment Mounted on Fixed Work Stands.

2-9.1

Electric wiring, outlets, and equipment, including lamps on or attached to fixed docks and stands that are located or likely to be located in hazardous areas as defined in 513-2 and 513-3 of NFPA 70, *National Electrical Code*, shall conform to the requirements for Class I, Group D, Division 2 locations.

2-9.2

Where docks and workstands are not located or likely to be located in hazardous areas as defined in 2-9.1 of this section, wiring and equipment shall conform to 513-4 and 513-5 of NFPA 70, *National Electrical Code*. Receptacles and attachment plugs shall be of the locking type that will not break apart readily.

2-10 Electrical Equipment Mounted on Movable Stands.

Movable docks and workstands with electrical equipment conforming to 2-9.2 of this chapter shall carry at least one permanently affixed warning sign to read: “Warning—Keep 5 Ft (1.5 M) Horizontally Clear of Aircraft Engines, Fuel Tank Areas, and Vents.”

Chapter 3 Aircraft Breathing-Oxygen Systems

3-1 Oxygen System Charging Operations and Safeguards.

3-1.1*

Because of the possibility of fire or explosion involving quantities of oxygen, the person choosing the site for oxygen charging operations shall consider such items as exposure of other aircraft, vehicles, structures, utilities, and people in the vicinity; and the accessibility of the aircraft to fire fighting equipment.

3-1.2

Where it is necessary to conduct gaseous oxygen system recharging or filling in a hangar or building, it shall be done under controlled conditions.

3-1.3

Liquid oxygen recharging shall not be conducted indoors under any conditions. At least a 50-ft (15.2-m) separation shall be maintained between a filling point and other aircraft, vehicles, and structures. Liquid oxygen charging operations shall not be performed within range of any drainage system elements, such as catch basins, through which a liquid oxygen spill could enter the drainage system since such systems can contain combustible material that could be extremely hazardous in contact with liquid oxygen in the confined space.

3-1.4

Good housekeeping practices, particularly with combustibles such as grease, lubricating oil, and asphalt, shall be maintained in the vicinity of oxygen charging operations.

3-1.5

Open flames, including smoking, shall be prohibited within 50 ft (15.2 m) of charging equipment.

3-1.6

Safeguards shall be taken while performing aircraft servicing or maintenance operations such as fueling, fuel and hydraulic system repairs, use of cleaning fluids or de-icing fluids, or operation of electrical equipment that can inherently or accidentally introduce ignition sources or combustibles concurrent with oxygen charging operations.

3-1.7

Only charging equipment and containers suitable for the specific aircraft breathing-oxygen system shall be used. Each container shall be identified by its marking before connecting it to the aircraft system. Equipment intended or used for other gases shall not be interchanged with oxygen equipment. High-pressure commercial containers, 1,800 psi (12.4 MPa) or higher, shall be connected through a high-pressure regulator specified for oxygen service to service low-pressure aircraft systems. Oxygen charging hoses shall be kept clean, capped when not in use, and clearly marked or tagged, “For Oxygen Use Only.”

3-1.8

Oil, grease, or other readily combustible substances shall not be permitted to come in contact with containers, flasks, valves, regulators, fittings, or any other part of the aircraft oxygen system or charging equipment. Oxygen equipment shall not be handled with oily gloves or tools. Charging operations shall not be performed while wearing oily or greasy clothing. Protective caps shall be kept on equipment as long as possible and replaced as soon as possible. Before charging, all connections shall be inspected for cleanliness. If dust, dirt, grease, or any other contaminant is found, it shall be removed with detergent or solvent approved for oxygen service. A small amount of oxygen shall be bled through hose or valve outlets before connecting to the fill fitting to eliminate foreign material that may escape external inspection.

3-1.8.1 The hose or valve outlet shall be aimed away from the body and equipment and only necessary valves shall be cracked open. A clean, dry container shall be available to collect any liquid oxygen discharge that might accidentally escape.

3-1.9

Only lubricating and thread compounds specifically approved for oxygen service under the pressures and temperatures involved shall be used. Other lubricants shall not be used.

3-1.10

Only valve packing and transfer hose gaskets that are suitable for oxygen service shall be used.

3-1.11

Damage to oxygen containers, hoses, flasks, or converters shall be avoided. Equipment shall be secured so that it cannot fall or roll.

3-1.12

Safety devices, identifying markings, symbols, and nameplates shall not be tampered with.

3-1.13

Valve outlets or controls that become clogged with ice shall be thawed with warm, not boiling, water.

3-1.14

Gaseous oxygen shall not be directed at the body or clothing, and liquid oxygen shall not be allowed to contact the body or clothing because of the possibility of both fire and personal injury.

3-1.15

Desiccant cartridges may be required to ensure that only dry oxygen is introduced and, where required, only fresh desiccant cartridges with filters shall be used.

3-1.16

Threaded fittings on regulators, container valve outlets, and hoses shall properly mate with each other. Connectors that do not fit shall not be forced. Fittings with worn or damaged threads shall be replaced.

3-1.17

After connecting containers or charging hoses to the oxygen system fill fitting, the connection shall be checked for gastightness by audible and visual means. Leak testing shall be done with a solution specifically approved for that particular gaseous, chemical, or liquid oxygen service.

3-1.18

Charging equipment discharge valves shall be closed when charging is completed.

3-2* Specific Cautions Applicable to Gaseous Breathing-Oxygen.

3-2.1

Container charging valves shall be opened slowly to minimize fast discharge of oxygen into the aircraft oxygen system, which can cause dangerous heating and result in a fire or explosion. Container valves shall be fully opened to prevent leakage around the valve stem.

3-2.2

Wrenches, hammers, or other tools shall not be used to force container valves. If a container valve cannot be hand operated, it shall be considered defective and taken out of service.

3-2.3

The aircraft oxygen system shall be charged to the established pressure after properly setting the supply regulating valve to the proper setting.

3-2.4

Where the aircraft oxygen system does not have filler valves and it is necessary to remove the aircraft containers themselves for recharging, the container valve shall be closed and all oxygen in the lines released to atmosphere before attempting container removal. Before removing the container from the aircraft, the container valve outlet shall be disconnected and capped, and all distribution lines shall be plugged.

3-3* Specific Cautions Applicable to Liquid Breathing-Oxygen.

3-3.1

Liquid oxygen shall not be permitted to contact any part of the body or clothes.

3-3.2

Personnel shall wear approved protective clothing and equipment while handling liquid oxygen equipment.

3-3.3

If liquid oxygen is spilled on clothing, the clothing shall be removed immediately and thoroughly aired before reuse.

3-3.4

Personnel who have handled liquid oxygen shall refrain from smoking for at least 15 minutes after leaving the charging area.

3-3.5

If it is necessary to remove moisture from the system, dry, oil-free air, gaseous oxygen, or nitrogen shall be used before introduction of liquid oxygen.

3-3.6

Because of its low temperature, liquid oxygen shall be handled in equipment constructed of materials suitable for the service. Ordinary rubber or plastic hoses, gaskets, or seals shall not be used.

3-3.7

When it is necessary to transfer liquid oxygen from one container to another, splashing shall be avoided. To avoid breakage, the receiving container shall be cooled gradually. Glass containers shall not be reused and containers used shall be clean.

3-3.8

When transferring liquid oxygen, valves shall not be left open all the way. To prevent the valves from freezing in the open position, they shall be opened wide and then immediately closed one-quarter turn.

3-3.9

Pressure relief devices shall be installed on all lines in which liquid oxygen might be trapped between closed valves and on closed containers.

3-3.10

Drip pans shall be used where pavement surfaces may be combustible or contaminated with dirt, oils, or similar materials that could ignite on contact with any spilled liquid oxygen. If a spill does occur, the flow of liquid shall be stopped where possible and the area involving the liquid spill shall be evacuated for the time necessary for liquid oxygen to evaporate. Personnel shall not walk on or move equipment through a liquid oxygen spill.

3-3.11*

The equipment manufacturer's instructions shall be followed when transferring liquid oxygen from the supply tank to the aircraft system.

3-4* Specific Cautions Applicable to Oxygen Generator Systems.

3-4.1

During maintenance operations that require the removal of the generator from its aircraft position, a safety cap shall be installed on the oxygen generator primer, since, when activated, it will generate temperatures up to 500°F (260°C).

3-4.2

If the generator is inadvertently activated, it shall immediately be placed on a noncombustible surface. However, if the generator is inadvertently activated in its aircraft position, it shall be left in its protected location.

3-5 Aircraft Breathing-Oxygen System Test and Repair Operations and Safeguards.

3-5.1*

When flow testing the aircraft system, the minimum amount of oxygen necessary to check the system shall be used.

3-5.2

Distribution lines within the aircraft shall be inspected periodically in accordance with the aircraft manufacturer's recommendations.

3-5.3

Pressure shall be released before attempting to tighten or loosen fittings unless the containers incorporate self-opening and self-venting valves.

3-5.4

When making pressure tests of oxygen distribution lines, the valves isolating the supply containers shall be closed. The system shall be tested in accordance with the specific instructions for the particular application. Oil or grease shall not be permitted to come in contact with escaping oxygen. Only leak testing solutions specifically approved for the purpose shall be used. All solutions shall be carefully cleaned off following the test.

3-5.5

Close check shall be kept on the vacuum available on all vacuum-insulated liquid oxygen tanks, and the manufacturer's instructions shall be closely followed.

3-5.6

When oxygen regulators or other oxygen system components on the pressure side of shutoff valves are removed for repair or replacement, the oxygen in the lines shall be released in the same manner as for container replacement specified in 3-2.4 of this chapter, and all disconnected lines plugged or capped.

3-6 Fire Protection.

3-6.1*

In case of a fire, the oxygen supply to the fire shall be shut off and the fire extinguished in the same manner as a fire in a normal air atmosphere.

3-6.2

An extinguisher having a rating of not less than 20-B and a minimum capacity of 15 lb (6.8 kg) of agent shall be located within 50 ft (15.2 m) of the work operation.

3-7* Breathing-Oxygen Cylinder Storage (DOT Gaseous Oxygen Cylinders and DOT-type 4L Cylinders of Liquid Oxygen).

3-7.1

Cylinders shall be stored in a definitely assigned location and protected against tampering by unauthorized individuals. Oxygen cylinders other than cylinders scheduled to be installed on the aircraft shall not be stored in aircraft servicing and maintenance areas of aircraft hangars.

3-7.2

Storage areas shall be reserved for liquid oxygen storage alone.

3-7.3

Oxygen storage areas shall be clearly placarded “Oxygen — No Smoking — No Open Flames” or equivalent.

3-7.4

Oxygen cylinders shall not be stored near flammable or combustible materials such as petroleum products, other readily combustible substances, or in the same area as compressed combustible gases. Empty and full cylinders shall be stored separately with empty cylinders clearly marked.

3-7.5

Each cylinder of aviator’s breathing oxygen shall be clearly marked to indicate its content. Aviator’s breathing oxygen shall be separately stored from all other oxygen cylinder supplies.

3-7.6

Cylinders shall be stored so that they are never allowed to reach a temperature exceeding 125°F (51.7°C). When stored in the open, they shall be protected against direct rays of the sun in localities where extreme temperatures prevail, from snow and ice where necessary, and from the ground beneath to prevent rusting.

3-7.7

Cylinders shall be protected against abnormal mechanical shock that could damage the cylinder, valve, or safety devices. Valve protection caps shall also be used when cylinders are not connected in use, providing that cylinders are designed for protection caps.

3-7.8

When moving cylinders, care shall be exercised to prevent dropping that might cause injury to the cylinder, valve, or safety devices. Lifting magnets, slings of rope or chain, or any other device in which the cylinders themselves form a part of the carrier shall not be used for hoisting oxygen cylinders. On hand or power trucks or tractors, cylinders shall be secured in an upright position.

3-7.9

DOT regulations regarding hydrostatic testing of DOT Specification 3A or 3AA cylinders shall be followed.

3-8* Liquid Breathing-Oxygen Storage (in Other than DOT-type 4L Cylinders).

3-8.1

Liquid oxygen containers shall be stored outdoors or in a detached, noncombustible structure in accordance with NFPA 50, *Standard for Bulk Oxygen Systems at Consumer Sites*, if the oxygen quantities fall within the scope of that standard. Smaller quantities shall be located outdoors in a detached noncombustible structure or in a cutoff room provided the cutoff room has effective ventilation and necessary doorways protected by fire doors with ramps or curbs to prevent entrance of flammable liquids and exit of liquid oxygen.

3-8.2

Storage areas shall be reserved for liquid oxygen storage alone and shall be clearly placarded "Oxygen — No Smoking — No Open Flames" or equivalent.

3-8.3

In outdoor areas, valves and safety devices shall be protected from ice and snow accumulations.

3-9* Gaseous Oxygen Equipment.

3-9.1*

Gaseous oxygen cylinders shall conform with DOT regulations; shall be equipped with a shutoff valve; shall be equipped with a frangible disc safety device that meets the requirements of CGA Pressure Relief Device Standards, Part 1 *Cylinders for Compressed Gases*, S-1.1; shall be connected to a common header by suitable pigtails strong enough to safely withstand full cylinder pressure; and shall be securely fastened to the cart.

3-9.2

Manifolds shall be constructed with sufficient strength to safely withstand full cylinder pressure. Manifolds shall be equipped with a valve connection for use in filling the cylinders and a valved outlet connection to which the regulator is attached.

3-9.3

An approved spring-loaded relief valve, preferably equipped with a metal seat, shall be provided to protect the hose and other equipment that may be attached to the outlet of the manifold.

3-9.4

A frangible disc shall be provided in the system, downstream of the manifold outlet, to function in the event that the safety relief valve malfunctions.

3-9.5* Regulators.

3-9.5.1 Regulators and components shall be approved for oxygen service.

3-9.5.2 Seats used in regulators shall be of a material chosen for maximum resistance to ignition in an oxygen atmosphere and that will have the required physical characteristics needed to maintain a gastight seal.

3-9.5.3 Regulators shall be provided with a suitable filter to prevent foreign particles from entering their inlet chambers.

3-9.5.4* Regulators shall be provided with a means for dissipating heat of recompression resulting from admission of high-pressure oxygen to the regulator which might otherwise cause the regulator high-pressure seat to ignite.

3-9.5.5 Regulators shall be equipped with gauges for indicating cylinder and discharge pressures.

3-9.6* Orifice.

3-9.6.1 Where a flow-restricting orifice is used, the orifice plate shall be constructed of approved material and shall be provided with a hole small enough to restrict the flow of oxygen to the equipment being filled to prevent development of excessive temperature in this equipment.

3-9.6.2 A pressure gauge shall be provided downstream of the orifice as a means of indicating the pressure in the aircraft oxygen system being filled.

3-9.7 Dehumidifiers or Dryers.

3-9.7.1 Any drying agent used shall be approved for use with oxygen.

3-9.7.2 The container housing the drying agent shall be constructed of an approved material and shall be strong enough to safely withstand the pressure to which it may be subjected. If steel is used, it shall be protected from corrosion.

3-9.7.3 Gasket materials used shall be approved for use with oxygen.

3-9.8 Hose.

3-9.8.1 Hose shall be approved for use with oxygen. It shall be strong enough to safely withstand any pressure to which it might be subjected.

3-9.8.2 Hose connections shall be secured to prevent loosening.

3-9.8.3 The outlet end of the hose shall be equipped with a shutoff valve.

3-9.8.4 The valve outlet shall be attachable to the system fill receptacle and shall be secured to prevent loosening.

3-9.9 Precautions.

3-9.9.1 No oil, grease, or other such combustible material shall be allowed to come in contact with the equipment.

3-9.9.2 Thread-sealing compounds, when used, shall be approved for use with oxygen.

3-9.9.3 All parts of the equipment shall be thoroughly cleaned of oil or grease before being assembled.

3-9.9.4 The cart manifold outlet valve immediately upstream of the regulator shall be in the closed position before the cylinder valves on the cart are opened.

3-9.9.5 Oxygen valves shall be opened slowly to avoid rapid pressure rise.

3-9.9.6 After opening cylinder valves on the cart, the manifold outlet valve shall not be opened for 60 sec in order to permit heat of recompression to dissipate.

3-9.9.7 The regulator shall be relieved of pressure (if the regulator is not the self-relieving type) before the manifold outlet valve to the regulator is opened.

3-9.9.8 Before disconnecting, the valve at the end of the fill hose shall be closed to avoid whipping.

3-10 Miscellaneous Requirements.

3-10.1

Oxygen shall not be used as a substitute for compressed air to operate pneumatic tools, or for pressurizing containers, paint spraying, or blowing out pipelines.

3-10.2

Gases shall not be mixed in an oxygen container.

Chapter 4 Aircraft Fuel System Maintenance

4-1 Fuel Transfer Equipment and Operations.

4-1.1*

The requirements of this section shall apply to aircraft fuel transfer operations during aircraft maintenance and overhaul operations. The fuel transfer operations shall include:

(a) Transferring fuel from one tank to another within an aircraft while on the ground preparatory to maintenance;

(b) Transferring fuel from a tank in an aircraft to a tank in ground equipment or vice versa in order to achieve a maintenance objective;

(c) Transferring fuel for the purpose of performing tank repairs, replacement of tank accessories, or balancing of fuel loads.

4-1.2

Aircraft fuel transfer operations shall use one of the systems as required by 4-1.4. Where fuels used have a flash point under 100°F (37.8°C), fuel transfer operations shall be conducted only out of doors.

4-1.3

Fuel transfer operations shall be conducted only out of doors if the aircraft tanks contained gasoline or JET B fuels during the preceding 20 flying hours.

4-1.4

A fixed fuel transfer piping system shall be used where fuel transfer operations are conducted on a routine basis.

4-1.4.1 A limited capacity self-contained trailer having a closed liquid transfer system shall be permitted to be used.

4-1.4.2 Self-propelled fuel servicing vehicles shall be permitted to be used.

4-1.5

Where a fixed fuel transfer piping system specified in 4-1.4 is used, it shall meet the requirements of Chapter 5 of NFPA 407, *Standard for Aircraft Fuel Servicing*.

4-1.5.1* Where fuel transfer piping extends into a hangar for aircraft fuel servicing operations, the portion of the piping located inside the hangar shall meet the requirements of Section 5-6 of NFPA 407, *Standard for Aircraft Fuel Servicing*.

4-1.6

Where self-propelled fuel servicing vehicles specified in 4-1.4.2 of this section are used, the fuel servicing vehicles shall meet the requirements of Chapter 4 of NFPA 407, *Standard for Aircraft Fuel Servicing*. In addition, the fuel servicing vehicles shall not be permitted inside the hangar and shall be so positioned outside the hangar as to be readily movable.

4-1.7*

All hangars used for these fuel transfer operations shall meet the requirements of NFPA 409, *Standard on Aircraft Hangars*.

4-1.8

Each fuel transfer operation shall be tailored to the fuel system design features of each type of aircraft and shall be performed only after the detailed procedures have been approved by the authority having jurisdiction.

4-1.9

Where multiple aircraft occupy one aircraft storage and servicing area, the location used for fuel transfer operations shall be identified.

4-1.10

During each fuel transfer operation, a trained and qualified person shall be assigned to specifically oversee the fire safety of the procedures used, including the handling of the fire protection equipment provided, spill emergency precautions, and ventilation techniques.

4-1.11

Any fueling hose used shall be continuous, without intermediate couplings, and shall conform to and be maintained in accordance with the requirements of Chapter 3 of NFPA 407, *Standard for Aircraft Fuel Servicing*.

4-1.12

Nozzles shall comply with the requirements of 4-9.3 or 4-9.4 of NFPA 407, *Standard for Aircraft Fuel Servicing*.

4-1.13

Only one aircraft shall undergo fuel transfer operations at any one time in a single aircraft storage and servicing area.

4-1.14

Any other simultaneous maintenance operation on that aircraft or within 25 ft (7.6 m) of the aircraft fuel system vents, fuel tank openings, or fuel servicing vehicle, if used, that can constitute a source of ignition of vapors that might be released during an operation shall not be permitted.

4-1.15

Personnel selected for fuel transfer operations shall have a thorough knowledge of the fuel system of the aircraft involved and the handling of flammable and combustible liquids, and shall be familiar with the operation and limitations of the fire extinguishing equipment available.

4-1.16

At least two extinguishers, each with a minimum rating of at least 80-B:C and a minimum capacity of 125 lb (57 kg) of agent, shall be located within a 50-ft (15-m) distance, one on each side of the aircraft undergoing maintenance.

4-1.17

All open flame and spark-producing equipment or devices within the vapor hazard area shall be shut down and not operated during the fuel transfer operations.

4-1.18

Electrical equipment used in the vapor hazard area shall be listed for use in Class I, Group D, Division 1, hazardous locations as defined by NFPA 70, *National Electrical Code*.

4-1.19

Procedures to guard against the accumulation of static electrical charges on the aircraft wing section or tank, the procedures of Section 2-3 of NFPA 407, *Standard for Aircraft Fuel Servicing*, shall be followed, and the equipment as specified in Section 2-15 of NFPA 409, *Standard on Aircraft Hangars*, shall be utilized. Apparel worn by personnel shall be made of material that will not accumulate static charges.

4-1.20

Internal combustion engine-powered equipment shall not be operated within 25 ft (7.6 m) of the aircraft fuel system vents or fuel tank openings prior to the start of fuel transfer operations.

4-1.21

When transferring fuel from an aircraft tank by suction using an external pump or fuel servicing truck, sufficient personnel shall be assigned to accomplish the operation, to prevent overfilling, and to guard against hose slippage and any flammable or combustible liquid spillage.

4-1.22

Aircraft radio, radar, strobe lights, and electronic transmitting equipment shall not be operated during fuel transfer operations.

4-1.23

Any fuel transfer hose nozzle used during these operations shall be electrically bonded to the aircraft. These bonding connections shall be made prior to the start of operations and maintained until after the fuel transfer operations have been completed.

4-1.24

When removing fuel from an aircraft tank by gravity, free fall of the fuel shall be avoided and a positive electrical bond shall be provided between the fuel tank and the receiving container.

4-1.25

Any spillage of fuel shall be handled in accordance with the requirements of Section 2-2 of NFPA 407, *Standard for Aircraft Fuel Servicing*.

4-1.26

When transferring aircraft fuels by hose into a tank or drum, the hose shall be extended and fixed below the liquid level of the receiving tank to reduce the hazard of liquid surface electrostatic generation.

4-2* Air Ventilation.

4-2.1

Air mover equipment used to secure air ventilation shall not create fire hazards.

4-2.2

Air movers designed to operate by expansion of compressed air or steam shall be used.

4-2.3

Compressed air shall not be introduced directly into aircraft fuel tanks for air ventilation purposes.

4-2.4

Where electrical equipment is used, the appliances shall conform to the types specified by Article 513 of NFPA 70, *National Electrical Code*.

4-2.5

A safety factor shall be included where the lower flammable limit is the criterion and 20 percent of the limits shown in Table 4-2.5 shall be considered the maximum allowable concentration of fuel vapor.

Table 4-2.5 Lower Flammable Limits of Aviation Fuels

	Lower Flammability Limit	
Fuel	**Percent by Volume**	**Parts per Million**
Aviation Gasoline (all grades)	1.4	14,000
Type A (kerosene) Turbine Fuel	0.6	6,000
Type B (gasoline-kerosene blend)	0.8	8,000

4-2.6

Instruments used to measure the lower flammable limit shall only be used by qualified personnel and shall be calibrated accurately for the type of vapors present and checked periodically against standard samples to assure maintenance of calibration. Sampling tubes shall be of a type that will be impervious to absorption of the vapors. Instruments depending upon electrical power, if not designed for use in Class I, Group D, Division 1 atmospheres as defined in NFPA 70, *National Electrical Code*, or certified as intrinsically safe because of their low energy design, shall be operated only in nonhazardous locations.

4-2.7

Personnel selected to conduct air ventilation work shall have considerable knowledge of and experience in handling flammable liquids and a thorough knowledge of the aircraft fuel system.

4-2.8

Aircraft shall be defueled in accordance with Section 4-1 of this chapter.

4-2.9*

Aircraft undergoing fuel tank ventilation procedures shall be segregated or isolated from other aircraft when the flash point of the fuel is less than 100°F (37.8°C) or until a flammable vapor concentration of 20 percent of the lower flammable limit is maintained.

4-2.10

When air ventilation is done in an enclosed hangar and where a closed ventilating system to discharge vapors from tanks to outside the hangar is not used and tank vapors are discharged into the hangar, tests shall be conducted to determine that the presence of such fuel vapor-laden air in the enclosed hangar does not constitute a hazard under the worst conditions that can normally be anticipated. Any flammable vapor concentration over 20 percent of the lower flammable limit downwind from any discharge point of a tank shall result in emergency revisions of procedures.

4-2.11

All open flame and spark-producing equipment or devices within the vapor hazard area shall be shut down and not operated during the ventilation procedures.

4-2.12

Electrical equipment used in the vapor hazard areas shall be listed for use in Class I, Group D, Division 1 hazardous locations as defined by NFPA 70, *National Electrical Code*.

4-2.13

Procedures to guard against the accumulation of static electrical charges on the aircraft wing section or tank shall utilize equipment as specified in Section 2-15 of NFPA 409, *Standard on Aircraft Hangars*. Exhaust equipment and the aircraft to be ventilated shall be electrically bonded and grounded. If ducting is used, a static bonding wire from each exhaust hose nozzle shall be connected to the aircraft before opening the fuel tank(s).

4-2.14

Aircraft electrical circuits that are in vapor-hazardous areas shall be de-energized.

4-2.15

Aircraft radar operations shall be controlled as required in Section 2-9 of NFPA 407, *Standard for Aircraft Fuel Servicing*.

4-2.16

Suitable warning signs shall be placed in conspicuous locations around the aircraft to indicate that tank ventilation is in progress until a flammable vapor concentration less than 20 percent of the lower flammable limit is maintained.

4-2.17*

Aircraft hangars in which this work is conducted shall meet the requirements of NFPA 409, *Standard on Aircraft Hangars*.

4-2.18

At least one extinguisher having a rating of not less than 20-B and a minimum capacity of 15 lb (6.8 kg) of agent shall be located within 50 ft (15.2 m) of the aircraft undergoing air ventilation.

4-2.19

When air exhaust only is used, precautions shall be taken to prevent building up a negative pressure, which might result in tank collapse. Where a blower is used, the volume and pressure of air introduced and discharged shall be so balanced that no pressure differential arises that might have an adverse effect on the tank structure.

4-2.20

The following equipment shall be required to accomplish air ventilation of aircraft fuel tanks:

(a) An air mover (exhaust) and, if circumstances dictate, a blower.

(b) When air ventilation is conducted in an enclosed hangar and conditions warrant, an exhaust system designed to discharge the vapors to the outside of the hangar.

(c)* Properly calibrated instruments designed to take readings of fuel and solvent vapor and oxygen concentrations within the tank volume being treated and appropriate gas sampling tubing.

4-3 Repair of Fuel Tanks.

4-3.1

Prior to conducting work on tanks, if it is necessary to defuel the tank or tanks to be repaired or inspected, such defueling operation shall be done in accordance with the requirements contained in Section 4-1 of this standard.

4-3.2

Residual fuel that cannot be withdrawn by normal defueling procedures shall be drained from the tanks by removal of tank access plates. With the opening of the tanks, air ventilation procedures shall be immediately instituted. Residual fuel shall be retrieved in the safest possible manner and the fuel prevented from excessively wetting the undersurface of the wing or dripping to the ground or ramp to form pools. The residual fuel shall be siphoned out of the tank or be manually sponged or mopped up from tank low points or where trapped by baffles or other internal structural members.

4-3.3

Prior to entry into the tank or the start of any repairs, tests shall be conducted to determine that a flammable vapor concentration less than 20 percent of the lower flammable limit exists.

4-3.4

When repairs are to be made to integral tanks that are interconnected to other integral or bladder tanks that do not require work, steps shall be taken to prevent vapors from entering the tank or the section undergoing repairs by plugging or taping interconnector openings, vent openings, or vent manifolds.

4-3.5

Personnel selected to perform fuel tank repair shall be trained in the hazardous characteristics of the work environment and the materials present.

4-3.6

The supervisor in charge of the operation shall have a thorough knowledge of the operation.

4-3.7

Aircraft hangars in which tank repair work is being conducted shall meet the requirements of NFPA 409, *Standard on Aircraft Hangars*.

4-3.8

When tank repair work is done in an enclosed hangar and tank vapors are discharged into the hangar, tests shall be conducted to determine that the presence of such fuel vapor-laden air does not constitute a hazard under the worst conditions that can normally be anticipated. Any flammable vapor concentration over 20 percent of the lower flammable limit anywhere within the hangar shall result in emergency revision of procedures.

4-3.9

All open flame and spark-producing equipment or devices within the vapor hazard area shall be shut down and not operated during the repair operations.

4-3.10

Electrical equipment used in the vapor hazard area shall be listed for use in Class I, Group D, Division 1 hazardous locations as defined by NFPA 70, *National Electrical Code*.

4-3.11

Procedures to guard against the accumulation of static electrical charges on the aircraft wing section or tank, the procedures of Section 2-3 of NFPA 407, *Standard for Aircraft Fuel Servicing*, shall be followed and the equipment as specified in Section 2-15 of NFPA 409, *Standard on Aircraft Hangars*, shall be utilized. Apparel worn by personnel shall be made of material that will not accumulate static charges.

4-3.12

When tank repairs are in progress, steps shall be taken to prevent all electrical and manual controls to the affected tank from being activated or energized.

4-3.13

Aircraft electrical circuits that are in vapor hazardous areas shall not be energized.

4-3.14

At least one extinguisher having a rating not less than 20-B and a minimum capacity of 15 lb (6.8 kg) of agent shall be located within 50 ft (15.2 m) of the aircraft.

4-3.15

Portable electrical lights used in tank repair operations shall be listed for use in Class I, Group D, Division 1 hazardous locations as defined by NFPA 70, *National Electrical Code*.

4-3.16

If flashlights are used within integral fuel cells, they shall be listed for use in Class I, Group D, Division 1 hazardous locations as defined by NFPA 70, *National Electrical Code*.

4-3.17

Containers used to transport flammable solvents used in effecting compound removal within the fuel tanks shall be equipped with positive closing or antispill lids to prevent spills while entering the fuel tank.

4-3.18

Electrical heating units used in tank repair operations shall be approved for use in Class I, Group D, Division 1 hazardous locations as defined by NFPA 70, *National Electrical Code*.

4-3.19

Blowers having electrical components used to accelerate cure time of sealant or to warm tank interiors shall be listed for use in Class I, Group D, Division 1 hazardous locations as defined by NFPA 70, *National Electrical Code*.

4-3.20* Additional Requirements for Repair of Integral Fuel Tanks.

4-3.20.1* Removal of existing sealant shall be accomplished with nonsparking metallic or hardwood scrapers. Plastic scrapers that tend to accumulate a static electric charge shall not be used.

4-3.20.2 Repairs necessitating structural rework shall be accomplished with compressed air-driven tools.

4-3.20.3* During top coating of fuel tank sealant base materials, extreme caution shall be taken to eliminate all possible ignition sources.

4-3.21* Additional Requirements for Repair of Bladder Tanks.

4-3.21.1* Fuel cell repair areas shall be well ventilated and segregated from other maintenance or assembly areas.

4-3.21.2 During application of coats of solvent and sealer over and under the patch, extreme caution shall be taken to eliminate all possible ignition sources.

4-3.21.3 Upon reinstallation of the cell, air ventilation procedures shall be started again and maintained until the fuel cell is closed.

4-3.22* Additional Requirements for Repair of Metal Tanks.

4-3.22.1 Required procedures for the safe removal of flammable vapors from metal tanks shall be as specified in NFPA 327, *Standard Procedures for Cleaning or Safeguarding Small Tanks and Containers.*

4-3.22.2 In addition to the precautions contained in NFPA 327, *Standard Procedures for Cleaning or Safeguarding Small Tanks and Containers Without Entry*, the following special precautions shall also be followed:

(a) Each compartment in a container having two or more compartments shall be treated in the same manner, regardless of which compartment is to be repaired.

(b) All tanks that have been cleaned and tested shall be stenciled and tagged. The stencil or tag shall include a phrase such as “Safe for Welding or Cutting,” the signature of the person so certifying, and the date.

4-4 Pressure Testing of Aircraft Fuel Systems.

4-4.1

The requirements of this section shall apply to aircraft fuel system pressure testing using a test fluid or fuel to assure integrity of the fuel system.

4-4.2

Where fuels used have a flash point under 100°F (37.8°C), fuel system pressure testing shall be conducted out of doors.

4-4.3

Aircraft fuel system pressure testing shall only be conducted out of doors if the aircraft tanks contained gasoline or JET B fuels during the preceding 20 flying hours.

4-4.4

Dump-valve tests involving fuel discharge shall also be done out of doors.

4-4.5

Fuel transfer operations done in conjunction with aircraft fuel system pressure testing shall comply with the requirements specified in Section 4-1 of this chapter.

4-4.6*

All hangars used for these operations shall meet the requirements of NFPA 409, *Standard on Aircraft Hangars*.

4-4.7

Each fuel system pressure testing operation shall be tailored to the fuel system design features of each type of aircraft and shall be performed only after the detailed procedures have been approved by the authority having jurisdiction.

4-4.8

An aircraft undergoing fuel system pressure testing shall be located in the hangar so that it or adjacent aircraft, unless on jacks or otherwise immobilized, can be rapidly withdrawn from the hangar in an emergency. Provisions shall be made to tow aircraft using preplanned techniques so that emergency fire control procedures can be undertaken.

4-4.9

Hangar doors shall be open when weather conditions permit and, if closed, unlatched and in such condition so that in an emergency the doors can be opened.

4-4.10

The amount of test fluid or fuel transferred shall be the minimum considered essential to each pressure testing operation.

4-4.11

The area used for fuel system pressure testing operations shall be placarded with suitably worded warning signs.

4-4.12

During each fuel system pressure testing operation, a trained and qualified person shall be assigned to specifically oversee the fire safety of the procedures used, including the handling of the fire protection equipment provided, spill emergency precautions, and ventilation techniques.

4-4.13

Any fueling hose used shall be continuous, without intermediate couplings, and shall conform and be maintained in accordance with Chapter 3 of NFPA 407, *Standard for Aircraft Fuel Servicing*.

4-4.14

Nozzles shall comply with the requirements of 4-9.3 or 4-9.4 of NFPA 407*, Standard for Aircraft Fuel Servicing*.

4-4.15

Only one aircraft shall undergo fuel system pressure testing at any one time in a single aircraft storage and servicing area.

4-4.16

Any other simultaneous maintenance operation on that aircraft or within 25 ft (7.6 m) of the aircraft fuel system vents, fuel tank openings, or fuel servicing vehicle (if used) that can constitute a source of ignition of vapors that might be released during an operation shall not be permitted.

4-4.17

Personnel selected for fuel system pressure testing operations shall have a thorough knowledge of the fuel system of the aircraft involved and the handling of flammable and combustible liquids, and shall be familiar with the operation and limitations of the fire extinguishing equipment available.

4-4.18

At least two extinguishers, each with a minimum rating of at least 80-B:C and a minimum capacity of 125 lb (57 kg) of agent, shall be located within a 50-ft (15.2-m) distance, one on each side of the aircraft undergoing maintenance.

4-4.19

All open flame and spark-producing equipment or devices within the vapor hazard area shall be shut down and not operated during the ventilation procedure.

4-4.20

Electrical equipment used in the vapor hazard area shall be approved for use in Class I, Group D, Division 1 hazardous locations as defined by NFPA 70, *National Electrical Code*.

4-4.21

Procedures to guard against the accumulation of static electrical charges on the aircraft wing section or tank shall utilize equipment as specified in Section 2-15 of NFPA 409, *Standard on Aircraft Hangars*. Apparel worn by personnel shall be made of material that will not accumulate static charges.

4-4.22

Internal combustion engine-powered equipment shall not be operated within 25 ft (8 m) of the aircraft fuel system vents or fuel tank openings prior to the start of fuel system pressure testing.

4-4.23

Ground power units, which are essential when employing the aircraft fuel booster pump for the fuel system pressure testing work, shall not be located within 25 ft (8 m) of the aircraft fuel system vents or fuel tank openings.

4-4.24

When transferring fuel from one aircraft tank to another by means of an aircraft fuel booster pump, sufficient personnel shall be assigned to accomplish the operation, to prevent overfilling and overpressurizing, and to detect possible leakage. Where such fuel transfer operations cannot be done utilizing the internal aircraft fuel system plumbing, there shall be sufficient personnel to perform the functions outlined in the previous sentence with particular attention given to the integrity of the external plumbing arrangement.

4-4.25

Aircraft radio, radar, strobe lights, and electronic transmitting equipment shall not be operated during fuel system pressure testing.

4-4.26

Caution shall be exercised to prevent intermixing of test fluids or different grades of fuel.

4-4.27

Any spillage of fuel shall be handled in accordance with the requirements given in Section 2-2 of NFPA 407, *Standard for Aircraft Fuel Servicing*.

Chapter 5 Aircraft External Cleaning, Painting, and Paint Removal

5-1 General.

5-1.1

Cleaning, painting, or paint removal operations using flammable or combustible materials shall be conducted in accordance with the requirements of this chapter.

5-1.2

Cleaning, painting, and paint removal of components and subassemblies that are small enough to be removed from the aircraft for work and that require a total application rate of more than 1 qt (1 L) of material in one hour, or the cumulative use of more than 1 gal (4 L) of material in eight hours shall be conducted in accordance with NFPA 33, *Standard for Spray Application Using Flammable and Combustible Materials*, and will not be discussed in this chapter.

5-1.3*

In selecting materials for cleaning, painting, and paint removal purposes, material with the highest flash point available shall be used.

5-2 Operational Sites and Precautions.

5-2.1*

When conducting cleaning, painting, or paint removal operations, the major consideration in choosing a location shall be that of good general ventilation and ease of cleanup.

5-2.2

When cleaning, painting, or paint removal operations of aircraft, major aircraft assemblies, or aircraft subassemblies that are not removable as specified in 5-1.2 are conducted in a hangar, that hangar shall meet the requirements of NFPA 409, *Standard on Aircraft Hangars*.

5-2.2.1 Where the hangars house only aircraft with drained and purged fuel tanks as defined in 1-3.7 of NFPA 409, *Standard on Aircraft Hangars*, the hangar shall be protected with at least an automatic sprinkler system that meets the requirements specified in Section 4-2 of NFPA 409.

5-2.3*

Ramp areas used for these maintenance procedures shall be servicing ramps not subject to public access. Sufficient clearance shall be maintained to avoid creating a hazard to adjacent aircraft or structures and to assure access by fire-fighting equipment, and the aircraft being worked on shall not be in the path of other normal aircraft movements on the ramp.

5-2.4

Where cleaning, painting, or paint removal operations are being conducted, no concurrent, potentially hazardous operations shall be conducted within 50 ft (15.2 m) of the working area. Even for touch-up operations, the area shall be inspected prior to the start of operations for any ignition sources within the working area and these sources shall be eliminated. Such conditions shall be maintained hazard-free during the entire work period.

5-2.5

Sufficient air movement to prevent flammable vapor concentrations at floor level, in floor pits and drains, and in aircraft compartments from reaching 20 percent of the lower explosive limit during these operations shall be provided by general ventilation, by opening of hangar doors, or by forced ventilation.

5-2.6

Fixed electrical equipment shall conform to Article 513 of NFPA 70, *National Electrical Code*. Temporary lighting used for general illumination during these operations shall be located so as not to be in direct range of any flammable sprays or liquids or in any “overspray” areas. Such equipment, if not listed for use in Class I, Group D hazardous locations, shall be of the enclosed and gasketed type to minimize the danger of breakage and reduce entrance of hazardous vapors within the fixtures.

5-2.7

The use of heat lamps to accelerate the drying of painted surfaces shall be prohibited unless used as part of an approved drying booth or enclosure in accordance with the requirements of NFPA 33, *Standard for Spray Application Using Flammable and Combustible Materials*, and NFPA 86, *Standard for Ovens and Furnaces*.

5-2.8

When cleaning or paint removal agents are applied through spray nozzles under pressure, the nozzle shall be of the self-closing type so that, when the hand of the operator is removed, the nozzle will automatically close.

5-2.9

Aircraft electrical systems shall be de-energized during cleaning, painting, and paint removal operations.

5-2.9.1 When aircraft power is required for concurrent operations in accordance with 5-2.4 of this chapter, the electrical equipment exposed to flammable or combustible liquids or vapors shall be de-energized.

5-3 Control of Flammable and Combustible Materials for Painting of Aircraft.

5-3.1

Supply stores of paints and flammable thinners and solvents shall be located in a separate building or segregated from the aircraft maintenance and servicing areas of hangars by a fire partition with openings that shall be protected by an approved and listed fire door. Storage shall conform to the requirements of NFPA 30, *Flammable and Combustible Liquids Code*.

5-3.2

Only an operational supply of paints and flammable solvents, limited to not more than one day's needs, shall be maintained in a hangar. These shall be in approved, marked containers located remotely from other operations. Dispensing drums, when essential to the operation, shall be equipped with positive acting pumps and pressure relief fittings and shall be provided with drip pans and static bonding clamps and cables. No pneumatic devices that pressurize the drum shall be used for dispensing the liquids.

5-3.3

Flammable and combustible liquids on the job shall be kept in approved containers, marked with the product name. Premixed paints shall be kept in their original metal containers, covered when not in use. Maximum solvent or paint container size on the job shall be 5 gal (20 L).

5-3.4

Epoxy or polyester resins shall not be stored close to ketone-type thinners.

5-3.5

Petroleum distillate suitable for use as a dry-cleaning solvent and other solvent cleaners such as mineral spirits, aliphatic naphtha, aromatic naphtha, trichlorethylene, xylene, methyl ethyl ketone, and other ketone-type thinners shall not be used in areas of aircraft oxygen systems.

5-4 Fire Extinguishing Equipment Requirements.

Regardless of how small, all aircraft on which cleaning, paint removal, or painting operations are performed shall have a minimum of one hand-portable fire extinguisher having at least a 20-B:C rating with a minimum capacity of 15 lb (6.8 kg) of agent and one nonsparking wheeled fire extinguisher having at least an 80-B:C rating with a minimum capacity of 125 lb (58 kg) of agent, located within 50 ft (15.2 m) of the operation, available for immediate use.

5-5 Housekeeping and General Safeguards.

5-5.1

Upon completion of each cleaning, paint removal, or painting operation, and at least once each day during the progress of the operation, all waste solvents, wiping waste, used masking tape, and waste paper shall be collected and safely disposed of. Under no circumstances shall flammable liquids or painting materials be dumped into sanitary or storm drains. Industrial waste disposal shall be made. Particular attention shall be paid to removing waste regularly from floor pits and trenches and from aircraft holds and recesses. Until properly disposed of, waste shall be kept in covered metal containers. Rags contaminated with finishing materials shall be kept in a separate container and not in those used to keep other waste materials.

5-5.2

The aircraft, unless immobilized, shall be parked in the painting area so that it can be readily removed in an emergency, with no obstacles between the aircraft and the doors.

5-5.3*

To reduce the hazards associated with static electricity, aircraft shall be electrically grounded when parked in aircraft hangars. The aircraft manufacturer's description and maintenance instructions shall be consulted regarding the location of grounding points on the aircraft and the number of grounding cables required.

5-5.4*

Spills shall be cleaned up as they occur.

5-5.5*

Other than designated safe smoking areas, smoking shall be prohibited in hangars or aircraft servicing ramps used for cleaning, paint removal, or painting operations.

5-5.6

Footwear with metal cleats or tacks shall not be permitted to be worn as they can cause sparks when scuffed along the floor.

5-5.7

No open flame shall be permitted in the vicinity of the working area.

5-6 Inspection and Preventive Maintenance.

5-6.1

Electrical equipment shall be inspected to ensure that it is being properly maintained in first-class condition and that it will not cause short circuits.

5-6.2

Grounding or bonding equipment shall be regularly inspected, properly maintained, and properly used.

5-6.3

Pumps, faucets, and pressure relief vents of containers used for flammable liquids or solvents shall be kept leak-free and functioning.

5-6.4

Any damage to containers, structure, seals, or flame arrestors shall be promptly and properly repaired.

5-6.5

Cleaning solution spray equipment, paint removal equipment, paint spray equipment, and other applicators shall be maintained in a safe condition.

5-6.6

Stands, docks, floors, filters, scaffolds, staging, and drop curtains shall be maintained on a regular basis to keep them sound and free from combustible accumulations.

5-6.7

Floors, roof trusses, light fixtures, and overhead equipment shall be regularly inspected for paint overspray and dust accumulation and cleaned when necessary.

Chapter 6 Aircraft Welding Operations

6-1 General Requirements.

6-1.1*

Aircraft welding operations shall conform to the requirements of this chapter.

6-1.2

Only gas-shielded arc-welding shall be performed on aircraft.

6-1.3

Only qualified welders, trained in the technique and familiar with the hazards involved, shall be permitted to do this work.

6-1.4*

A written, special welding permit shall be obtained for each welding operation conducted on an aircraft from an individual designated by management as responsible for authorizing welding operations. A welding fire safety check list shall also be tailor-made and used to cover the individual hazards of each type of operation. If a hazard is encountered that is not covered on the check list, work shall be stopped until the individual designated by management as responsible for authorizing welding operations provides any needed additional guidance.

6-1.5

No welding shall be conducted, or welding equipment brought to the work area, until a permit has been issued.

6-1.6

No other work shall be permitted within a 25-ft (7.6-m) radius of the location of any gas-shielded arc-welding operation.

6-1.7

If other aircraft are located adjacent to the welding operation, the person responsible for each aircraft shall be notified in advance that welding is to be conducted.

6-2 Flammable Vapors.

6-2.1

Welding shall not be done on an aircraft while work is in progress on any system or component of that aircraft which contains, or did contain, fuel or other flammable or combustible liquids.

6-2.2

Welding shall not be done on an aircraft while work is in progress on the fuel systems on any other aircraft within 50 ft (15.2 m) from the point of welding.

6-2.3

Fuel tank access plates and any fuel tank openings shall be closed on all aircraft within 50 ft (15 m) from the point of any welding. All fuel lines, valves, manifolds, and other fuel components on the aircraft on which welding is being done shall be in place, secured, or capped prior to the start of welding operations and during such welding operations.

6-2.4*

All fuel tank vents on the aircraft being worked on and the vents of other aircraft within a 50-ft (15-m) radius of the welding operation shall be plugged or covered prior to the start of welding operations and during such welding operations.

6-2.5

Prior to the start of welding and at least every 15 minutes during the welding operation, a qualified person shall check with a combustible gas analyzer to assure that flammable vapors do not reach 20 percent of the lower explosive limit whenever welding is being done in the vicinity of sources of flammable vapors. Floor drains in the area of a welding operation, when conducted in a hangar, shall be checked in the same manner.

6-3 Equipment.

6-3.1

Welding generating equipment shall be placarded as follows: “Warning—Keep 5 Ft (1.5 M) Horizontally Clear of Aircraft Engines, Fuel Tank Areas, and Vents.”

6-3.2

Welding equipment shall have no electrical components other than flexible lead cables within 18 in. (457 mm) of the floor. The ground leads shall be as close to the area to be welded as possible, and clamps used on such ground leads shall be of the “C” clamp type, not the clip type. Components that could produce arcs, sparks, or hot metal under any condition of operation shall be of the totally enclosed type or shall have suitable guards or spacing in compliance with the requirements of Article 500, Hazardous (Classified) Locations, of NFPA 70, *National Electrical Code*. The inert gas cylinder shall be securely fastened to prevent tipping and the regulator and gage shall be in proper working condition.

6-4 Fire Protection.

6-4.1

When welding operations are performed in an aircraft hangar, that hangar shall meet the requirements of NFPA 409, *Standard on Aircraft Hangars*.

6-4.1.1 Where the hangars house only aircraft with drained and purged fuel tanks as defined in 1-3.7 of NFPA 409, *Standard on Aircraft Hangars*, the hangar shall be protected with at least an automatic sprinkler system that meets the requirements specified in Section 4-2 of NFPA 409.

6-4.2

Any welding performed shall take into consideration the type of automatic fire detection equipment installed in the hangar to avoid false alarms or accidental actuation of the fire protection equipment provided.

6-4.3

The specific location where the welding is being done shall be roped off or otherwise segregated by physical barrier to prevent unintended entry into the welding area. A placard reading "Welding Operations in Progress" shall be prominently displayed.

6-4.4

Good housekeeping shall prevail in the welding area.

6-4.5

At least one hand-portable fire extinguisher having a minimum rating of 20-B with a minimum capacity of 15 lb (6.8 kg) of agent shall be positioned in the immediate area of the welding operation ready for instant use, and one wheeled extinguisher having a minimum rating of 80-B with a minimum capacity of 125 lb (58 kg) of agent shall be readily available.

6-4.6

A qualified fire watcher shall be assigned to operate this equipment and shall monitor the entire welding operation. In the event a hazardous condition develops, the fire watcher shall have the authority to stop the welding operation.

Chapter 7 Interior Cleaning and Refurbishing Operations

7-1 General Requirements.

7-1.1*

Flammable liquid cleaning agents shall not be used. Combustible liquid cleaning agents shall be permitted to be used.

7-1.2*

Aircraft cleaning or refurbishing operations using combustible liquids shall be conducted in accordance with this chapter.

7-2 Precautions for Combustible Liquid Cleaning Agents.

7-2.1

Combustible liquids shall be stored and controlled in accordance with the provisions of NFPA 30, *Flammable and Combustible Liquids Code*. Container storage areas shall be segregated from the aircraft maintenance and servicing area of hangars by a fire partition with openings protected by an approved fire door or located in a separate building.

7-2.2

Combustible liquids shall be handled only in approved containers appropriately marked.

7-2.3

Aircraft interiors shall be provided with ventilation sufficient at all times to prevent the accumulation of flammable or combustible vapors. To accomplish this, doors to interiors shall be open to secure maximum advantage of natural ventilation. Where such natural ventilation is insufficient, approved mechanical ventilation equipment shall be provided and used to prevent the accumulation of flammable or combustible vapors from reaching 20 percent of the lower flammability limit of the particular vapor being used.

7-2.4

All open flame and spark-producing equipment or devices that might be brought within the vapor hazard area shall be shut down and not operated during the period when flammable or combustible vapors might exist.

7-2.5

Electrical equipment of a hand-portable nature used within a vapor hazard area shall be of the type approved for use in Class I, Group D, Division 1 hazardous locations as defined by NFPA 70, *National Electrical Code*.

7-2.6

Temporary lighting used outside the hazard area for general illumination within an interior during cleaning and refurbishing operations, that is not listed for use in Class I, Group D hazardous locations, shall be enclosed and gasketed to reduce entrance of hazardous vapors within the fixtures, attached and located so as to minimize danger of breakage, and installed so as not to be in direct contact with any combustible liquids or “overspray.”

7-2.7

Switches to aircraft interior lighting and to the aircraft electrical system components within the interior area shall not be worked on or switched on or off during cleaning operations where flammable vapors might exist.

7-3 Fire Protection Requirements.

7-3.1*

During such cleaning or refurbishing operations in an aircraft outside of the hangar, portable fire extinguishers having a minimum rating of 4-A:20-B with a minimum capacity of 15 lb (6.8 kg) of agent shall be provided at cabin entrances.

7-3.2

When such cleaning or refurbishing operations are performed in an aircraft hangar, that hangar shall meet the requirements of NFPA 409, *Standard on Aircraft Hangars*.

7-3.2.1 Where the hangars house only aircraft with drained and purged fuel tanks as defined in 1-3.7 of NFPA 409, *Standard on Aircraft Hangars*, the hangar shall be protected with at least an automatic sprinkler system that meets the requirements specified in Section 4-2 of NFPA 409.

7-3.2.2 In all cases, aircraft undergoing such operations in any hangar shall also have the portable fire extinguishers required in 7-3.1 of this section.

7-3.2.3 In all cases, aircraft undergoing such operations in a Group I or II hangar shall also have at least one hose line available with an adjustable spray nozzle and a discharge of not less than 50 gpm (189.25 L/min). This hose line shall be capable of reaching into the cabin area.

Chapter 8 Aircraft Ramp Fire Protection

8-1 General Requirements.

8-1.1

This chapter shall apply to the minimum requirements for fire safety on aircraft ramps.

8-1.2

The requirements of NFPA 407, *Standard on Aircraft Fuel Servicing*, shall be met during aircraft fuel servicing operations.

8-1.3

Smoking shall be prohibited on the ramp.

8-1.4

Open flames shall not be allowed within a 50-ft (15-m) radius of aircraft.

8-1.5

A Permit to Work shall be obtained before commencement of any open flame or hot work on the ramp. The permit shall be issued on a daily basis by the authority having jurisdiction.

8-1.6

Aircraft shall be kept under observation when connected to ground power.

8-1.7

Rubbish shall not be allowed to accumulate on the ramp and shall be disposed of in approved containers.

8-1.8

All waste flammable liquids shall be placed in approved containers prior to disposal.

8-1.9

Flammable liquids shall not be placed in trash cans or poured down storm drains.

8-2 Fire Extinguishers.

8-2.1*

At least one wheeled extinguisher having a rating of not less than 80-B and a minimum capacity of not less than 125 lb (55 kg) shall be provided at each gate or stand, or at intervals of 200 ft (61 m) along the length of aircraft ramps.

8-2.2

All portable extinguishers shall meet the requirements of NFPA 10, *Standard for Portable Fire Extinguishers*.

8-3 Fire Incidents.

8-3.1*

In the event of a fire on or adjacent to an aircraft, the captain, crew, or personnel on board shall be alerted immediately so that an evacuation can be initiated.

8-3.2*

The fire shall be reported immediately to the fire department and the exact location and aircraft registration given by one or more of the following methods:

(a) Telephone;

(b) Mobile or portable radio;

(c) Aircraft radio;

(d) Fire alarm.

8-3.3*

All personnel employed on aircraft ramps shall be given training on action to take in case of fire. This shall include hands-on training in the use of portable and wheeled extinguishers.

Chapter 9 Referenced Publications

9-1

The following documents or portions thereof are referenced within this standard and shall be considered part of the requirements of this document. The edition indicated for each reference is the current edition as of the date of the NFPA issuance of this document.

9-1.1 NFPA Publications.

National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.

NFPA 10, *Standard for Portable Extinguishers*, 1994 edition.

NFPA 30, *Flammable and Combustible Liquids Code*, 1993 edition.

NFPA 33, *Standard for Spray Application Using Flammable and Combustible Materials*, 1989 edition.

NFPA 50, *Standard for Bulk Oxygen Systems at Consumer Sites*, 1990 edition.

NFPA 70, *National Electrical Code*, 1993 edition.

NFPA 86, *Standard for Ovens and Furnaces*, 1990 edition.

NFPA 321, *Standard on Basic Classification of Flammable and Combustible Liquids*, 1991 edition.

NFPA 327, *Standard Procedures for Cleaning or Safeguarding Small Tanks and Containers Without Entry*, 1993 edition.

NFPA 407, *Standard for Aircraft Fuel Servicing*, 1990 edition.

NFPA 409, *Standard on Aircraft Hangars*, 1990 edition.

9-1.2 Other Publications.

9-1.2.1 CGA Publication. Compressed Gas Association, Inc., 1235 Jefferson Davis Highway, Arlington, VA 22202.

CGA Pressure Relief Device Standards, Part 1 - *Cylinders for Compressed Gases*, S-1.1, 1979.

Appendix A Explanatory Material

This Appendix is not a part of the requirements of this NFPA document but is included for informational purposes only.

A-1-3 Cleaning, Interior.

The principal areas of aircraft interiors that may need periodic cleaning are:

(a) Aircraft passenger interior areas (seats, carpets, side panels, headliners, overhead racks, curtains, ashtrays, windows, doors, and decorative panels of plastic, wood, or similar materials).

(b) Aircraft flight station areas (similar materials to those found in passenger interior areas plus instrument panels, control pedestals, glare shields, flooring materials, metallic surfaces of instruments and flight control equipment, electrical cables and contacts, etc.).

(c) Lavatories and buffets (similar materials to those found in passenger cabin areas plus toilet facilities, metal fixtures and trim, trash containers, cabinets, wash and sink basins, mirrors, ovens, etc.).

A-1-4

Metric units of measurement in this standard are in accordance with the modernized metric system known as the International System of Units (SI). One unit (liter), outside of but recognized by SI, is commonly used in international fire protection. For additional information, see ASTM E380, *Standard for Metric Practice*.

The conversion procedure for the SI units is to multiply the quantity by the conversion factor and then round the result to the appropriate number of significant digits.

A-2-2.3

A short across these terminals can burn or weld metal, and resultant arcs can cause an explosion if the short circuit occurs in the presence of a flammable vapor.

Wrenches and other hand tools should be used carefully to avoid short circuits. Finger rings, wrist watches, wrist chains, etc., should not be worn while working near battery terminals because a short circuit could cause an arc or result in a severe burn.

A-2-2.5

Most aircraft have battery compartments designed for in-flight ventilation only, and if batteries are charged in such compartments while the aircraft is on the ground, an explosive gas-air mixture can be trapped in the battery compartment.

A-2-2.11

Lead-acid batteries can release hydrogen gas during charging, and any sulfuric acid vapors released are corrosive. Vented nickel-cadmium batteries can release oxygen and hydrogen if overcharged. Sealed nickel-cadmium batteries can swell, vent, or rupture if charged at a greater than recommended rate or if excessively overcharged.

A-2-3.6

This is extremely important, because in some aircraft the battery switch has a midposition, and, if the switch is in this position and the batteries have not been removed or disconnected, the batteries will be charged in the aircraft battery compartment, giving off excessive heat and hydrogen gas.

A-2-4.7

See Figure A-2-4.7.

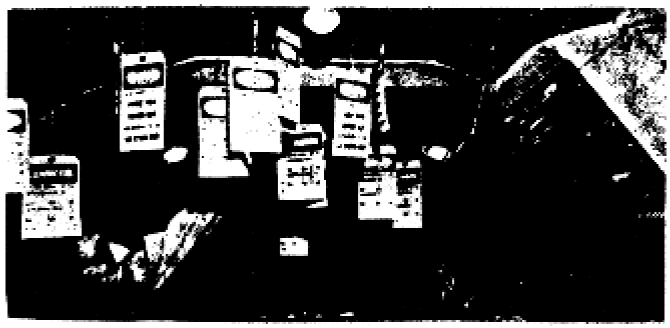


Figure A-2-4.7 Typical illustration of the use of a "tag-out" system.
(Courtesy of American Airlines, Inc.)

A-2-4.8(a) No fewer than two persons should work on energized electrical systems in areas containing flammable fluid lines.

A-3-1.1

For information on bulk storage of oxygen, see NFPA 50, *Standard for Bulk Oxygen Systems at Consumer Sites*, and NFPA 53, *Guide on Fire Hazards in Oxygen-Enriched Atmospheres*.

Description of Gaseous and Liquid Oxygen.

Current aircraft breathing-oxygen systems can utilize either gaseous or liquid oxygen or a chemical-oxygen generator.

Gaseous oxygen is colorless, odorless, tasteless, and nontoxic. It comprises about 21 percent of normal air by volume and is about 10 percent heavier than air. Above its critical temperature of 180.4°F (82.4°C), oxygen can exist only as a gas regardless of the pressure exerted upon it.

Liquid oxygen is a light blue, transparent liquid that flows like water. It boils at –297°F (-147.2°C) at standard atmospheric pressure. The gaseous oxygen formed at room temperature [70°F (21°C)] and standard atmospheric pressure [29.92 in. (760 mm) of mercury] by vaporization of liquid oxygen will occupy a volume about 862 times that occupied by the original liquid. If a volume of liquid oxygen is confined and allowed to warm to room temperature, the attempt of the vaporizing oxygen to expand will result in the attaining of extremely high pressures [in the order of 40,000 psi (276 MPa)]. For this reason, liquid oxygen containers must be fitted with safety relief devices or vented to the atmosphere.

Hazards.

Both gaseous and liquid oxygen are stable materials and are nonflammable. Combustible materials ignite more readily in an oxygen-enriched atmosphere. The intensity of a fire increases in the presence of oxygen. This makes it very important to keep concentrations of oxygen separated from combustibles and from any source of ignition. Therefore, the highest standards of housekeeping are essential in areas where oxygen is stored or serviced. Physical damage to or failure of oxygen containers, valves, or plumbing can result in an explosive rupture in oxygen system components with resultant danger to life, limb, and property.

Combustible materials, particularly easily ignitible flammable liquids and lubricating oil, are especially hazardous when present inside the aircraft breathing-oxygen systems where the oxygen concentrations are high. There have been several incidents where explosive rupture of system components has resulted under these circumstances.

In addition to aggravating the fire hazard, liquid oxygen will cause severe “burns” (frostbite) in contact with the skin because of its low temperature.

Since oxygen-enriched atmospheres accelerate the corrosion process, only materials approved for oxygen service should be used.

A-3-2

Low-Pressure Breathing-Oxygen Systems.

These fixed systems utilize compressed gaseous oxygen stored in containers having a maximum service pressure of about 400 to 450 psi (2.76 to 3.10 MPa). A typical system consists of one or more containers manifolded to suitable oxygen distribution piping, check valves to isolate individual containers, relief devices to prevent container overpressure from overcharging or heating, a pressure gauge to indicate quantity of oxygen available, a manual shutoff valve, valves to isolate portions of the system, a fill fitting to permit charging the system, and one or more of the types of regulators previously described.

High-Pressure Breathing-Oxygen Systems.

These fixed systems utilize compressed gaseous oxygen stored in containers having a maximum service pressure of about 1800 to 2200 psi (12.4 to 15.2 MPa). A typical system is quite similar to the low-pressure systems except that fill fittings may sometimes not be provided. (In such systems, the entire container is replaced with a full container as needed.)

Portable Equipment.

Portable equipment (“walk-around bottles”) utilize compressed gaseous oxygen in either the low- or high-pressure containers. A typical system is comprised of either a demand or continuous flow regulator, a pressure reducer, a quick disconnect fill fitting equipped with a check valve for charging, a container pressure gauge, and a snap-in connection for mask fittings.

A-3-3 Liquid Breathing-Oxygen Converter Systems.

These fixed systems utilize liquid oxygen stored in highly insulated containers that can be vented to the atmosphere or operated under low or moderate pressure. A typical system utilizes demand or continuous flow regulators and the liquid oxygen is passed through tubing where it vaporizes and then through a warm-up coil (heat exchanger) to raise the temperature of the gaseous oxygen to a comfortable breathing level. A pressure-operated control valve maintains the desired delivery pressure and volume. Overpressure relief devices vent excessive pressures overboard. Other components include a cockpit oxygen quantity indicator, a fill fitting, and the necessary distribution piping and check valves. Some liquid oxygen containers are spherical in shape and are surrounded by integral vaporizer tubing. Others have the vaporizer tubing separate from the container. Liquid breathing-oxygen charging operations are not regarded as more hazardous than gaseous breathing-oxygen charging operations; however, a spill of liquid oxygen introduces a new hazard that should be specifically safeguarded.

A-3-3.11

The following recommendations outline procedures considered typical; however, variances in design between aircraft systems and charging equipment might require deviations. Always observe the equipment manufacturer's instructions.

(a) Before transferring liquid oxygen from the supply tank to the aircraft system, be sure that the pressure relief valve on the supply tank is operating.

(b) To develop the desired pressure to effect transfer, close the vent valve and open the pressure buildup valve slowly. Allow the pressure to reach the desired level and then close the pressure buildup valve.

(c) Attach the transfer hose to the tank and open the fill-drain valve. Purge the transfer hose in accordance with the specific instructions of the manufacturer and then close the fill-drain valve.

(d) After purging, attach the hose to the fill fitting in the aircraft oxygen system and open the fill-drain valve slowly.

(e) Fill the aircraft converter until a steady flow of liquid (caught in a clean, dry container specifically reserved for this purpose) comes from the converter vent line, decreasing the built-up pressure in the supply tank as the converter approaches the full condition by opening the supply tank vent valve.

(f) When the aircraft converter is full, close the fill-drain valve on the tank and release pressure in the transfer hose by opening the pressure relief valve. It might be necessary to operate the pressure relief valve several times until there is no further pressure rise. Disconnect the transfer hose from the aircraft fill fitting.

(g) Replace the cap on the aircraft fill fitting and set the buildup and vent valves in accordance with the manufacturer's instructions.

Liquid oxygen might contain trace quantities of dissolved hydrocarbon impurities. Repeated recharging of containers from which oxygen is withdrawn as a gas, without periodically warming such containers sufficiently to volatilize and clean out the impurities, can concentrate these impurities to an objectionable degree. Normally this will not be a problem if the system is warmed and purged at each major overhaul period.

A-3-4 Oxygen Generator Systems.

These systems utilize a generator with a chemical core. Chemical reaction is initiated by an electrically fired squib or a firing pin. Upon initiation, the generator supplies oxygen to the masks. The generator systems are installed on some turbine aircraft to supply emergency oxygen to the passengers and interior attendants in the event of loss of interior pressure.

A-3-5.1

If available, breathing air, rather than oxygen, can be used for this purpose.

A-3-6.1

If liquid oxygen is involved in a fire, it is normally desirable to allow the fire to burn until the liquid oxygen present in the fire area has evaporated. The combustible materials ignited should be attacked with the appropriate agent. Oxygen can combine with a number of combustible materials and cause an explosion. Liquid oxygen, as a vigorous oxidizing agent, cannot be effectively blanketed by extinguishing agents.

A-3-7 Breathing-Oxygen Cylinder Storage.

(a) Gaseous breathing oxygen is generally received in high-pressure [1800 to 3000 psi (12.4 to 20.7 MPa)] containers. The containers can be conventional commercial cylinders, in which case they are stored and transported to the charging site where they are used to charge the aircraft system storage containers. In some instances the aircraft system storage containers themselves might be received, in which case they are stored and transported to the charging site and interchanged with the empty containers in the aircraft system.

(b) Liquid breathing oxygen is generally received in a tank car or truck and is transferred to a storage vessel. It is then transferred as needed to a mobile charging vehicle and transported to the charging site where it is used to charge the converter in the aircraft system.

(c) In general, the applicable provisions of NFPA 51, *Standard for the Design and Installation of Oxygen-Fuel Gas Systems for Welding, Cutting, and Allied Processes*, and NFPA 50, *Standard for Bulk Oxygen Systems at Consumer Sites*, should be followed. NFPA 51 is applicable to cylinder storage in smaller quantities. NFPA 50 is applicable to larger systems of both gaseous and liquid oxygen.

A-3-8 Liquid Oxygen Storage Equipment.

In the United States, liquid oxygen storage containers are fabricated from materials meeting the impact test requirements of Paragraph UG-84 of the ANSI B31.1 *Boiler and Pressure Vessel Code*, Section VIII — Unfired Pressure Vessels, or meet the specifications of DOT for 4L cylinders. Vessels (other than DOT 4L cylinders) operating at pressures above 15 psig (103 kPa gauge) are designed in accordance with the further appropriate provisions of the ASME code. A gastight, carbon steel jacket generally encloses the liquid-holding container, the annular space is filled with noncombustible insulation, and a high vacuum is maintained in the space. Containers used for this purpose should be painted and legibly marked “Aviator’s Breathing Oxygen” in a manner similar to that described in A-3-9(e).

A-3-9 Gaseous Oxygen Equipment.

(*See also A-3-8*.)

(a) In the United States, regulations of the Department of Transportation (DOT) govern the type and capacity of containers in which commercial oxygen as a nonflammable compressed gas can be transported and stored. In Canada, specifications issued by the Board of Transport Commissioners apply. In other countries, similar rules are generally issued by the appropriate governmental agencies. In the United States, commercial oxygen at a pressure in excess of 40 psi (276 kPa) absolute [25 psig (272 kPa gauge) approximate] at 70°F (21.1°C) is most commonly packed and shipped in seamless steel cylinders constructed to DOT Specification 3A or 3AA.

(b) Commercial oxygen container valve outlet and inlet connections should conform to standards prepared by the Compressed Gas Association, Inc., that have been adopted by both the American and Canadian standards associations.

(c) Most oxygen cylinders are required by DOT to be equipped with safety devices. Usually, this is accomplished by using a frangible disc, a fusible metal core, or a combination thereof on the cylinder valve, designed to release the gas in the event the cylinder is subjected to an abnormally high temperature, as in a fire.

(d) Each DOT 3A and 3AA cylinder is marked with a service pressure, and filling of the cylinder at 70°F (21.1°C) must not exceed 110 percent of the service pressure if the cylinder is marked with a plus sign following the last test date and if the cylinder valve is fitted with a frangible disc (without fusible metal) safety device; if not so marked and fitted, the filling must not exceed the marked service pressure.

(e) DOT cylinders are required to have the DOT specification number followed by the service pressure (e.g., DOT3A2015); a serial number and identifying symbol (registered with the Bureau of Explosives) of the purchaser, user, or maker; the inspector's official mark and the date of the test to which the cylinder was subjected in manufacture; and the word "Spun" or "Plug" when an end enclosure is made by the spinning process or effected by plugging. In addition, cylinders used in this service should be painted and legibly marked "Aviator's Breathing Oxygen" as recommended by CGA C-4, *Method for Marking Portable Compressed Gas Cylinders to Identify the Material Contained*.

A-3-9.1

The conventional equipment consists of a wheeled cart on which is mounted a number of high-pressure cylinders with an attached manifold. A pressure-reducing device, such as a regulator, installed on the manifold is provided with an outlet connection to which the hose used to fill the aircraft oxygen system is attached. A dehumidifier, used to dry the oxygen, is sometimes interposed between the regulator outlet and the filling hose.

A-3-9.5 Types of Aircraft Breathing-Oxygen Regulators.

The three basic types of aircraft breathing-oxygen regulators are supplied from fixed or portable oxygen systems as described in A-3-2, A-3-3, and A-3-4.

(a) A continuous flow-type regulator, automatic or manual, is a means for increasing the flow with altitude. With this regulator, the breathing-oxygen flow is fixed for any given adjustment and does not vary automatically to suit work or rest conditions.

(b) A demand-type regulator allows breathing oxygen to flow only when a suction is applied, as by inhaling through a mask or tube. This regulator might feed only pure breathing oxygen, or the diluter demand-type may have automatic means for mixing air with the pure breathing oxygen to maintain the partial pressure of oxygen in the lungs at a preset, low-altitude condition up to some predetermined altitude. An emergency valve for eliminating the dilution of pure breathing oxygen is normally provided.

(c) A pressure breathing demand-type regulator, when used with the proper mask, imposes a predetermined pressure upon the lungs at certain altitudes [usually above 30,000 ft (9000 m)]. Below that altitude, the regulator functions as an ordinary diluter demand-type.

A-3-9.5.4 This can be a dead-end chamber directly connected to the inlet passage of the regulator or some other heat-absorbing device.

A-3-9.6 Pressure reduction can also be achieved through the use of a flow-restricting orifice installed at the manifold outlet valve or in the line between the outer valve and the cylinder to be filled. This arrangement, unlike the one employing a regulator, requires the presence of an operator to shut off the gas supply from the manifold when the aircraft oxygen system comes up to specified pressure.

A-4-1.1

See NFPA 407, *Standard for Aircraft Fuel Servicing*, for aircraft fuel transfer operations not associated with aircraft maintenance or overhaul operations.

A-4-1.5.1 While Chapter 5 of NFPA 407 does not allow fuel transfer piping to be located in a building, NFPA 407 does not apply to aircraft fuel system maintenance operations. (*See Section 1-1 of NFPA 407, Standard for Aircraft Fuel Servicing*.) This document, NFPA 410, covers aircraft fuel system maintenance, and the provisions of 4-1.5.1 allow the fuel transfer piping to extend into a hangar for aircraft fuel system maintenance operations provided that it is protected as stated.

A-4-1.7

Aircraft that are brought into a heated hangar from a cold outdoor atmosphere should be carefully watched for fuel expansion, because normalization to ambient temperature can take several hours.

A-4-2

Air ventilation of aircraft fuel tanks is recommended for the sole purpose of rendering the atmosphere in an aircraft fuel tank more suitable for personnel to enter the tank area for inspection or work purposes. This basically requires reducing the fuel tank vapors to below a predetermined toxic threshold (unless respiratory protection is provided) and below the predetermined lower flammability limits of the flammable vapors and, then, maintaining this condition throughout the period of inspection or work. Air ventilation is not a method of inerting an aircraft fuel tank, and this distinction must be clearly understood.

Air ventilation should be accomplished by exhausting the fuel tank atmosphere of toxic and flammable concentrations of fuel vapors through a specified vapor exhaust system with or without a blower designed to augment the sweeping of the fuel vapors from the tank. The design of the air ventilation system used on any particular aircraft must be tailor-engineered to satisfy the requirements of the aircraft in question, and detailed specifications will be required for each fuel tank configuration to properly achieve these objectives.

When using air ventilation procedures, there might be times when the fuel vapor-air mixture in the tank will be within the flammability range. During such periods, a fire and explosion hazard exists. It is thus vitally important that there be no ignition sources within the tank or within reach of the vapors being discharged from the tank.

Successful use of air ventilation depends heavily on three basic factors:

(a) Complete drainage of the fuel tank to be treated, including siphoning, sponging, or mopping up of fuel residues that might be trapped in the tank. During the latter operations, extreme caution is necessary to prevent accidental ignition of the vapors that will be present.

Fuel vapor concentrations must be maintained below 20 percent of lower flammable limit.

(b) Establishment of adequate air circulation through the tank to assure that the air movement rids the entire tank volume of hazardous quantities of fuel vapors. This requires tests on each tank configuration to establish the correct tank openings required, the rate of air movement, and the time needed. Such tests should include combustible vapor measurements of the entire tank volume to assure that no hazardous vapor pockets remain, especially in tank corners that might not be properly air ventilated if the air currents established by the exhaust and/or blower systems are ineffective.

(c) Continuation of air ventilation during the entire period that the tanks are open and any work is being done.

Under some conditions (particularly in integral-type fuel tanks having sealing compounds at tank joints and in baffled tanks where drainage through baffles might not be efficient), it is possible to reinstate a flammable fuel vapor-air concentration after initial ventilation has secured a satisfactory condition. Where flammable solvents are used to remove or replace sealant or where fuel vapors are released by the breaking of sealing compound blisters, a localized toxic or flammable vapor atmosphere can be created. To minimize this type of hazard, nonflammable solvents should be used wherever possible. Periodic checks should be made with a combustibles detector or other appropriate instrument in the area of work to assure the maintenance of a safe tank atmosphere.

The periodic checks are to check any unusual conditions that might develop and to help maintain a fire safety consciousness among the employees involved in fuel tank maintenance work.

Example Procedure, Air Ventilation (Enclosed Aircraft Hangar). This example procedure is illustrative of one method only and can be altered as required for different situations and conditions. However, these principles should be followed.

(a) Place the aircraft in the proper position in the hangar with fuel tanks drained, residual fuel mopped up, and the proper underwing tank plates removed; where possible, air ventilation should have been started outdoors and a satisfactory combustible instrument reading indicating a nonhazardous tank atmosphere secured.

(b) Guard against static spark hazards by electrically bonding and grounding exhaust equipment and the aircraft to be ventilated. If ducting is used, connect a static bonding wire from each exhaust hose nozzle to the aircraft before opening the fuel tank(s).

(c) When a closed ventilating system (*see 4-2.10*) is used, connect the prearranged exhaust system to an explosionproof exhaust fan designed to extract air at a specific rate. (Airflow must be calibrated for each tank volume and configuration to assure effective fuel vapor removal.)

NOTE: It cannot be assumed that a high rate of airflow through a tank will be more efficient than a moderate rate. Complete sweeping of the tank volume is desired without bypassing corners or creating excessive turbulence.

(d) When portable air movers or blowers are used, place this equipment in position, secure the equipment, and, for exhaust systems, seal around tank attachment. When ducting is used with air-moving equipment to help sweep vapors from the tank, bond the ducting (if conductive) to the aircraft and pressurize the ducting before making a tight connection around attachment openings. Having a positive pressure in the ducting should prevent any flammable vapors from entering the ducting that might ignite by a source of ignition in the air-moving equipment. The air introduced into the tank through the ducting should be clean and should not contain any entrained dust, moisture, or flammable vapors. When exhaust ducts are used, the air should be exhausted to a location not containing any ignition source and to a point outside the hangar or building.

(e) Maintain the ventilation for the time prescribed to achieve a safe atmosphere within the tank (*see 4-2.5*) and during all tank maintenance work. Check the actual conditions periodically with the combustibles detector.

(f) Halt tank maintenance operations when any unsafe condition develops, and do not resume operations until a safe condition is restored. (*See 4-2.10.*)

(g) When work has been completed, remove ventilating equipment. When ducts are used, remove the exhaust nozzles from the tank(s) leaving the exhaust fan operating and static bonding wire(s) attached. Replace tank caps or plates. Allow the exhaust fan to run for three or four minutes to permit removal of all vapors from the ducts. Disconnect the static bond wires from the aircraft and turn off the exhaust fan.

A-4-2.9

Where such facilities are available and practical, hangar docks (open-faced structures) are preferable to enclosed hangars for the balance of the air ventilation procedure.

A-4-2.17

See A-4-1.7.

A-4-2.20

(c) **Warning!** The reliance placed on combustible vapor detectors requires great care in the selection of the proper instrument and thorough knowledge of its capabilities and limitations. Expert maintenance is normally required. Only persons specially trained in the use of the instruments selected and in interpreting the measurements secured should be relied on to perform the required tests.

A-4-3.20

The designation integral fuel tank is confined to fuel containers whose boundaries are made up of as nearly 100 percent primary structure as possible, primary structure being the elements of the aircraft that carry the major stresses of flight, such as stressed skin, spar caps, spar webs, etc. Integral fuel tanks can be either part of the wing or the fuselage. Integral fuel tanks discussed here are confined to the types that are basically without gasket materials installed in the seams, the structural cavities being made fuel-tight by the installation of a sealing material after the completion of fabrication of the unit where the tank is located.

Example Procedure. The example procedure detailed herein might have to be altered under certain conditions depending on aircraft design factors and the fuel tank configuration.

(a) Place the aircraft in the proper position in the hangar dock or hangar building with fuel tanks, fuel lines, and cross-feed system drained as required. Consideration should be given to cross-feed and selector valve positions to obtain the desired isolation of fuel within the system.

(b) Suitable warning signs should be placed in conspicuous locations around the aircraft to indicate that tank repairs and air ventilation are in progress.

(c) Guard against static spark hazards by electrically grounding the aircraft to be repaired.

(d) Attach air movers or blowers to the exhaust system, seal around tank attachments, and electrically bond to the aircraft. For blower system, remove the necessary tank door and insert the exhaust hose nozzle, bond, and ground as necessary to guard against static spark hazards.

(e) Maintain ventilation for the time prescribed to achieve a safe atmosphere within the tank and during all tank repair work. Check the actual conditions periodically with the combustible gas detector and maintain frequent verbal contact with personnel within tanks. (*See 4-2*.)

(f) Remove additional tank access doors when necessary to effect repairs. Such removal can expose additional quantities of trapped or residual fuel. When such is the case, applicable precautions, as outlined in the text, should be followed.

A-4-3.20.1 Removal of sealant and cleanup of the area to be resealed often requires considerable agitation of the solvent or stripper. When flammable solvents or strippers are used for this operation, it becomes imperative that extreme caution be exercised to eliminate all possible ignition sources. To minimize this type of hazard, nonflammable solvents should be used whenever possible, recognizing, however, that nonflammable solvents might be more toxic.

A-4-3.20.3 Application of top coating by spray method is not recommended.

A-4-3.21

The designation "bladder tank" includes both collapsible and self-sealing tanks. The bladders themselves are of a special synthetic rubber and fabric material. Normally these cells have a fairly low melting point and change pliability with relatively small changes in temperature. Pliability is a critical quality in the fuel cell material. A plasticizing agent is compounded into the synthetic rubber to keep it pliable. Fuel tends to extract the plasticizing agent; however, this is not detrimental since fuel itself keeps the material pliable.

Example Procedure. The example procedure detailed herein might have to be altered under certain conditions depending on aircraft design factors and the type of bladders being repaired.

(a) Place the aircraft in the proper position in the hangar dock or hangar building with fuel tanks, fuel lines, and cross-feed system drained. Consideration should be given to cross-feed and selector valve positions to obtain the desired isolation of fuel within the system.

(b) Suitable warning signs should be placed in conspicuous locations around the aircraft to indicate that fuel system repairs and air ventilation are in progress.

(c) Guard against static spark hazards by grounding the aircraft.

(d) Remove the access doors and open the fuel cells.

(e) Attach the ventilation system and maintain for the time prescribed to achieve a safe atmosphere within the tank and until the cell is ready for removal. Check the actual conditions periodically with a combustible gas detector. (*See 4-2*.)

NOTE: Turbine-powered aircraft are most frequently fueled with Type A (kerosene) fuel. The use of a combustible vapor detector can be recommended only to detect the possible mixtures of lower flash point Type

B turbine fuels or aviation gasoline.

(f) Remove all of the equipment, lines, etc., and detach the cell from the fuel cell cavity. Prior to the removal of the cell, all equipment, pumps, lines, etc., should be removed, and any residual fuel remaining in the cell should be siphoned out or manually sponged or mopped up from cell low points.

(g) Collapse the cell and remove from the aircraft.

(h) After removal of the cell, the cell cavity should be checked with a combustible gas detector to be certain that a safe condition exists.

(i) Transport the cell to the repair area and preserve in accordance with the manufacturer's recommendations.

A-4-3.21.1 It is recommended that aircraft be segregated or isolated during the time fuel cells are being removed.

A-4-3.22

The term "metal tanks" applies to all types of metal fuel containers, including surge and vent tanks that can be removed from the aircraft for shop or bench repair, but does not include metal fuel containers that are an integral part of the aircraft that can, under certain major overhaul conditions, be removed from the primary portion of the airframe.

A-4-4.6

See A-4-1.7.

A-5-1.3 Paint Removal.

(a) Polyurethane paint systems consisting of an epoxy coat and a polyurethane topcoat have been widely used in the aerospace industry. One phase of the aircraft surface conditioning requires solvent wipe-down just before applying the epoxy primer. This solvent could be methyl ethyl ketone or aliphatic naphta, both of which have low flash points and require safeguards of proper ventilation and control of ignition sources to reduce the incidence of fire.

(b) Walkway coatings are applied to internal and external areas of aircraft that are normally walked upon frequently by personnel. It is used to protect the metal surface and to provide a safe footing for personnel. This paint system is suitable for brush or roller application, but the thinner most used is xylene with a flash point less than 100°F (38°C), which requires the appropriate fire hazard safeguards.

(c) In the aerospace industry the low flash point paint removers have largely been replaced by self-extinguishing water-rinsable type with a low fire hazard.

A-5-2.1

All areas used for paint finishing should be provided with mechanical ventilation discharging to the outside atmosphere of such capacity to permit between 20 to 30 air changes per hour by volume. Exhaust from spray booths should be of such capacity as to provide an airflow of not less than 250 linear ft per min (76.2 m/min). Air exhausted from spraying operations should not be circulated. Exhaust ducts should pass directly through the nearest outside wall or through the roof. Ducts should not pass through fire walls or the floor. Air intake should be from the outside atmosphere (through steam blast coils where necessary). Air intake should be from other areas provided the atmosphere does not contain flammable vapor or residue. Air intake openings should be protected with automatic dampers that close in the event of a fire. Hangar ventilation will reduce human respiratory hazard, but dermatic hazard, eye hazard, and other protective health measures should also be considered. See also NFPA 90A, *Standard for the Installation of Air Conditioning and Ventilating Systems*, and NFPA 91, *Standard for Exhaust Systems for Air Conveying of Materials*.

A-5-2.3

See NFPA 415, *Standard on Aircraft Fueling Ramp Drainage*, for applicable data.

A-5-5.3

When aircraft maintenance platforms are used in the painting operation, they should be bonded to the aircraft. Cables used for grounding painting equipment such as metal tables, racks, tanks, maintenance stands, etc., should be attached in such a manner that they cannot be disconnected or broken if the equipment is accidentally moved.

A-5-5.4

Hangar and shop floors should be protected from fuel, oil, and other spillage through the use of drip trays or collection containers.

A-5-5.5

Cigarette lighters and matches should not be carried by personnel.

A-6-1.1

The chapter covers the welding of aircraft by the gas-shielded arc method. Welding operations other than those on aircraft should conform to NFPA 51, *Standard for the Design and Installation of Oxygen-Fuel Gas Systems for Welding, Cutting, and Allied Processes*; NFPA 51B, *Standard for Fire Prevention in Use of Cutting and Welding Processes*; and ANSI Z49.1, *Safety in Welding and Cutting*.

Occasionally it is necessary to stress-relieve certain portions of the aircraft engines or structures by normalizing through the use of an oxyacetylene flame. Silver soldering is also required on certain electrical connections and fluid lines. The same basic precautions outlined herein should apply to these operations.

NFPA 51B, *Standard for Fire Protection in Use of Cutting and Welding Processes*, gives the basic rules for cutting and welding processes using electric arcs or oxy-fuel flames.

NFPA 51, *Standard for the Design and Installation of Oxygen-Fuel Gas Systems for Welding, Cutting, and Allied Processes*, applies to the installation and operation of all gas welding and cutting systems. Structural welding in hangars should follow the procedures outlined in NFPA 51 and NFPA 51B. It is recommended that any contract to perform structural or general welding in a hangar take special note of the hazard to the contents. Aircraft should be removed wherever possible and the precautions herein applied as applicable.

A-6-1.4

See Figures A-6-1.4(a) and (b).

Welding Permit
Required for Each Welding Operation

Aircraft Type ____________ No. ____________

Part to Be Worked on ______________________

____

Specify in detail, e.g., "Inlet Vanes on No. 3 Engine"

Location of Work ______________________

Name of Mechanic ______________________

Name of Fire Watcher ______________________

Date of Work: ______________ Approvals:

Shift __________ Foreman ______________

Fire Watcher ______________________

Figure A-6-1.4(a) Typical Welding Permit and Aircraft Welding Firesafety Check List

Attach to Welding Permit — Display at Job Site
Gase-Shielded Arc Welding

Safeguarding Fuel Systems	YES	NO
Fuel system closed on aircraft being welded	____	____
Portions of fuel system on adjacent aircraft within 100 ft (30 m) from welding point closed	____	____
Fuel tank access plates in place	____	____
Fuel tank fill and vent openings closed, covered, or plugged	____	____
Fuel lines, valves, mainfolds in place, secured or capped	____	____
Streamers attached to covered fuel vents	____	____
Pressure removed from fuel systems	____	____
Area including hangar floor drains checked with Combustible Gase Analyzer	____	____
Ramp area work location checked for sources of flammable/combustible vapors	____	____
Safeguarding Other Work		
All other work suspended within 20 ft (6 m) of welding point	____	____
Area placarded: "Welding Operations in Progress	____	____
Adjacent workers notified pior to start of operation	____	____
Housekeeping		
Area cleaned where weld is to be made	____	____
Combustible materials removed in surrounding area	____	____
Area cleared of any oil or fuel spills	____	____
Drains checked in area for oil contamination	____	____
Welding Equipment		
Generators 5 ft (1.5 m) clear of aircraft engine, fuel tanks	____	____
Electrical equipment 18 in. (375 mm) (minimum) off floor	____	____
Ground leads clamped to grounding plug	____	____
Gase cylinder securely fastened to prevent tipping	____	____
Regulators, gages working properly	____	____
Mobility of Aircraft		
Aircraft parking brakes off and wheels chocked	____	____
Tug available — tow bar attached	____	____
Hangar doors open	____	____
Path cleared to permit towing aircraft outside	____	____
Qualified tow operator available and alerted	____	____
Fire Protection		
Fire extinguisher (20-B rating minimum) immediately adjacent	____	____
Fire extinguisher (80-B) rating minimum) wheeled, within 100 ft (30 m)	____	____
Automatic sprinkler protection operable	____	____
Fire watcher assigned, on duty	____	____

Approved Fire Watcher

Date ______________ Supervisor ______________

Figure A-6-1.4(b) Aircraft Welding Firesafety Check List

A-6-2.4

Streamers should be attached to covered vents and promptly removed after completion of the welding operation.

A-7-1.1 Nonflammable Agents and Solvents.

(a) In selecting nonflammable agents, care should be exercised to assure that a toxicity hazard is not introduced that cannot be effectively controlled by practical protective means under normal working conditions. While health hazards are outside the scope of this standard, a number of effective nonflammable cleaning agents (e.g., carbon tetrachloride) do present a serious toxicity problem. Industrial hygienists and safety professionals as well as fire protection engineers should be consulted before selecting any cleaning agent or solvent for this use.

(b) Types of Nonflammable Agents and Solvents.

1. *Detergents and Soaps*. These have widespread application for most aircraft cleaning operations involving fabrics, headliners, rugs, windows, and similar surfaces that are not easily damaged by water solutions because they are colorfast and nonshrinkable. Care should be taken to prevent leaching of water-soluble fire-retardant salts that might have been used to treat such materials in order to reduce their flame spread characteristics.

2. *Alkaline Cleaners*. Most of these agents are water soluble and thus have no fire hazard properties. They can be used on fabrics, headliners, rugs, and similar surfaces in the same manner as detergent and soap solutions with only minor added limitations resulting from their inherent caustic characteristics that might increase their efficiency as cleaning agents but result in somewhat greater deteriorating effects on certain fabrics and plastics.

3. *Acid Solutions*. A number of proprietary acid solutions are available for use as cleaning agents. They are normally mild solutions designed primarily to remove carbon smut or corrosive stains. As water-based solutions, they have no flash point but should require more careful and judicious use, not only to prevent damage to fabrics, plastics, or other surfaces, but also to protect the skin and clothing of those using the materials.

4. *Deodorizing or Disinfecting Agents*. A number of proprietary agents useful for aircraft interior deodorizing or disinfecting are nonflammable. Most of these are designed for spray application (aerosol type) and have a nonflammable pressurizing agent, but check this carefully as some might contain a flammable compressed gas for pressurization.

5. *Abrasives*. Some proprietary nonflammable mild abrasive materials are available for rejuvenating painted or polished surfaces. They present no fire hazard.

6. *Dry-Cleaning Agents*. Perchlorethylene and trichlorethylene, as used at ambient temperatures, are examples of nonflammable dry-cleaning agents. These materials do have a toxicity hazard requiring care in their use. Fire-retardant-treated materials might be adversely affected by the application of these agents as can water-soluble agents.

A-7-1.2

The Underwriters Laboratories Inc. Gas and Oil Equipment List contains a listing of liquid products classified by fire hazard. *Flash Point Index of Trade Name Liquids* gives important details on the fire hazard properties of some 8,800 trade name liquids (including cleaning agents) commonly used in the United States and Canada. See NFPA 325, *Fire Hazard Properties of Flammable Liquids, Gases, and Volatile Solids*, for a complete listing.

A-7-3.1

All-purpose (ABC) dry chemical-type extinguishers should not be used in situations where aluminum corrosion is a problem.

A-8-2.1

At least one portable extinguisher having a rating of not less than 20-B and a minimum capacity of not less than 15 lb (6.8 kg) should be provided on mobile service equipment including:

(a) Air conditioning units;

(b) Aircraft tractors;

(c) Air starter units;

(d) Cabin service trucks;

(e) Catering trucks;

(f) Container loaders;

(g) De-icer trucks;

(h) Engine driven passenger loading steps;

(i) Ground power units;

(j) Mobile lounges.

In those vehicles classified in (d), (e), (g), (h), and (j), consideration should be given to placing an extinguisher on both the chassis and the elevated section of the vehicle.

At least one portable extinguisher having a rating of not less than 5-B and a minimum capacity of 3 lb (1.5 kg) should be provided on other miscellaneous motorized vehicles that operate within 25-ft (8-m) radius of any part of the aircraft.

A-8-3.1

When an aircraft lands with a suspected fire or smoke warning in a cargo hold, the fire department should be informed immediately and a full passenger evacuation of the aircraft should be carried out before any hold door is opened. Hold doors should not be opened until the fire department is in attendance at the aircraft.

Failure to observe this recommendation could result in an in-rush of air into the hold, which could cause the fire to erupt, creating danger if passengers or crew are still onboard the aircraft.

A-8-3.2

When a fire is discovered in an aircraft, immediate action should be taken to extinguish it, with either the fire extinguishers available in the aircraft or those situated on the ramp. The fire department should be informed immediately.

In some instances, it might not be possible to extinguish the fire, or alternatively, the fire might have developed to a point where the readily available fire extinguishers are inadequate. If so, the progress of the fire and the damage caused can be reduced by vacating the aircraft and closing all doors, hatches, etc.

A-8-3.3

When dealing with aircraft wheel fires, approach should be made from a fore or aft direction and never from the side. The heating of aircraft wheels and tires presents a potential explosion hazard, greatly emphasized when fire is present. It is important not to mistake hot brakes for brake fires. Hot brakes will normally cool by themselves, or with the assistance of an air cooling appliance, without the use of an extinguishing agent.

Since the heat is transferred to the wheel from the brake, it is essential that the extinguishing agent be applied to the brake area. Once the fire has been extinguished, further extinguishing agent should not be discharged for cooling purposes.

Too rapid cooling of a hot wheel, especially if localized, can cause explosive failure of the wheel. Solid streams of water or carbon dioxide should not be used. Halon 1211 is an effective extinguishing agent for wheel fires. Dry chemical has a limited cooling effect, but is an effective extinguishing agent.

Appendix B Referenced Publications

B-1

The following documents or portions thereof are referenced within this standard for informational purposes only and thus are not considered part of the requirements of this document. The edition indicated for each reference is the current edition as of the date of the NFPA issuance of this document.

B-1.1 NFPA Publications.

National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.

NFPA 50, *Standard for Bulk Oxygen Systems at Consumer Sites*, 1990 edition.

NFPA 51, *Standard for the Design and Installation of Oxygen-Fuel Gas Systems for Welding, Cutting, and Allied Processes*, 1992 edition.

NFPA 51B, *Standard for Fire Prevention in Use of Cutting and Welding Processes*, 1994 edition.

NFPA 53, *Guide on Fire Hazards in Oxygen-Enriched Atmospheres*, 1994 edition.

NFPA 90A, *Standard for the Installation of Air Conditioning and Ventilating Systems*, 1993 edition.

NFPA 91, *Standard for Exhaust Systems for Air Conveying of Materials*, 1992 edition.

NFPA 325, *Fire Hazard Properties of Flammable Liquids, Gases, and Volatile Solids*, 1994 edition.

NFPA 407, *Standard for Aircraft Fuel Servicing*, 1990 edition.

NFPA 415, *Standard on Aircraft Fueling Ramp Drainage*, 1992 edition.

NFPA *Flash Point Index of Trade Name Liquids*, 9th edition (1978).

B-1-2 Other Publications.

B-1-2.1 ANSI Publication.

American National Standards Institute, 1430 Broadway, New York, NY 10018.

ANSI Z49.1-1983, *Safety in Welding and Cutting.*

B-1-2.2 ASME Publication.

American Society of Mechanical Engineers, 345 East 47th Street, New York, NY 10017.

ANSI B31.1-1983, *Boiler and Pressure Vessel Code.*

B-1-2.3 ASTM Publication.

American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103.

ASTM E380-1986, *Standard for Metric Practice.*

B-1-2.4 CGA Publication.

Compressed Gas Association, 1235 Jefferson Davis Highway, Arlington, VA 22202-4100.

CGA C-4 (1990), *Method for Marking Portable Compressed Gas Cylinders to Identify the Material Contained.*

NFPA 412

1993 Edition

Standard for Evaluating Aircraft Rescue and Fire Fighting

Foam Equipment

1993 Edition

This edition of NFPA 412, *Standard for Evaluating Aircraft Rescue and Fire Fighting Foam Equipment*, was prepared by the Technical Committee on Aircraft Rescue and Fire Fighting and acted on by the National Fire Protection Association, Inc. at its Annual Meeting held May 24-27, 1993, in Orlando, FL. It was issued by the Standards Council on July 23, 1993, with an effective date of August 20, 1993, and supersedes all previous editions.

The 1993 edition of this document has been approved by the American National Standards Institute.

Changes other than editorial are indicated by a vertical rule in the margin of the pages on which they appear. These lines are included as an aid to the user in identifying changes from the previous edition.

Origin and Development of NFPA 412

Work on this material started in 1955 when the NFPA Subcommittee on Aircraft Rescue and Fire Fighting (as then constituted) initiated a study on methods of evaluating aircraft rescue and fire fighting vehicles. A tentative text was adopted by the Association in 1957 and a revised text officially adopted in 1959. Revisions were made in 1960, 1964, 1965, 1969, 1973, and 1974. With the introduction of new types of foam liquid concentrates over the years for this specialized service, the text has been broadened to cover these concentrates.

In 1987 the standard was completely revised to bring it into conformance with the *Manual of Style* and to refine the test methods.

The 1993 edition of the standard establishes a single test method for expansion and drainage for all foams (previously there were two). Additionally, information on using the conductivity meter for determining foam solution concentration was added.

The following task group was appointed to assist in the 1993 revision of this standard:

Task Group on Evaluating Foam Fire Fighting Equipment on Aircraft Rescue and Fire Fighting Vehicles

Joseph L. Scheffey, Chair, Hughes Associates Inc., MD; William M. Carey, Underwriters Laboratories Inc., IL; Robert L. Darwin, Dept. of the Navy — Fire Protection Div., DC; James F. O'Regan, Westboro, MA; John M. Schuster, 3M Company, MN

Technical Committee on Aircraft Rescue and Fire Fighting

John F. Rooney, *Chair*
Tucson, AZ

James F. O'Regan, *Vice Chair*
Westboro, MA

Edward B. (Ned) Aksim, Chubb Nat'l Foam, PA

Brian Boucher, Canadian Air Line Pilots Assn., ON
Rep. Canadian Air Line Pilots Assn.

Booker T. Burley, Atlanta Int'l Airport, GA

Robert L. Darwin, Dept. of the Navy - Fire Protection Div., DC

Robert J. Donahue, Massport, MA

B. V. Hewes, Airport Safety Services, GA

Paul O. Huston, Amerex Corp., AL
Rep. Fire Equipment Manufacturers' Assn., Inc.

L. M. Krasner, Factory Mutual Research Corp., MA

Dan Lanzdorf, Oshkosh Truck Corp., WI

Thomas J. Lett, Albuquerque Fire & Safety Assoc. Inc., NM
Rep. NFPA Fire Service Section

D. Robin Maryon, Simon Gloster Saro Ltd., England

John J. O'Sullivan, British Airways, England

Davis R. Parsons, Los Angeles City Fire Dept., CA

Gaetan Perron, Dept. of Nat'l Defence, ON

Robert E. Reyff, U.S. Air Force, FL

Paul R. Robinson, Kennesaw, GA
Rep. Air Line Pilots Assn.

Bertrand F. Ruggles, FAA Dept. of Transportation, DC

Joseph L. Scheffey, Hughes Assoc. Inc., MD

John M. Schuster, 3M Co., MN

John X. Stefanki, John X. Stefanki Inc., CA

William J. Wenzel, Voorheesville, NY
Rep. Walter Truck Corp.

Ronald O. Wikander, Lockheed Aeronautical Systems Co., GA

Larry E. Williams, Williams Training Assoc., AR

Richard Winnie, Emergency One Inc., FL

Joseph A. Wright, DOT/FAA Technical Center, NJ
Rep. Atlantic City Int'l Airport, NJ

Alternates

Joan M. Leedy, 3M Co., MN
(Alt. to J. M. Schuster)

Dave Lenz, Oshkosh Truck Corp., WI
(Alt. to D. Lanzdorf)

Robert Maxwell, Dept. of Nat'l Defence, ON
(Alt. to G. Perron)

Thomas E. McMaster, Los Angeles City Fire Dept., CA
(Alt. to D. R. Parsons)

William E. Moore, U.S. Federal Aviation Admin., CO
(Alt. to B. F. Ruggles)

Bruce A. Warner, ICI Americas Inc., DE
(Alt. to P. O. Huston)

William S. Weeks, Airline Pilots Assn., NC
(Alt. to P. R. Robinson)

Nonvoting

Bernard Brown, Civil Aviation Authority, England

John E. Lodge, Lodge Fire Protection Consultancy Ltd., England
(Member Emeritus)

Edward F. Mudrowsky, Nat'l Transportation SafetyBoard, DC

David F. Short, Carmichael Int'l Ltd., England

Mark T. Conroy, NFPA Staff Liaison

This list represents the membership at the time the Committee was balloted on the text of this edition. Since that time, changes in the membership may have occurred.

NOTE: Membership on a Committee shall not in and of itself constitute an endorsement of the Association or any document developed by the Committee on which the member serves.

Committee Scope: This Committee shall have primary responsibility for the criteria for aircraft rescue and fire fighting services and equipment, procedures for handling aircraft fire emergencies, and for specialized vehicles used to perform these functions at airports with particular emphasis on saving lives and reducing injuries coincident with aircraft fires following impact or aircraft ground fires. The Committee also shall have responsibility for developing aircraft fire investigation procedures as an aid to accident prevention and the saving of lives in future aircraft accidents involving fire.

NFPA 412
Standard for
Evaluating Aircraft Rescue and
Fire Fighting Foam Equipment

1993 Edition

NOTICE: An asterisk (*) following the number or letter designating a paragraph indicates explanatory material on that paragraph in Appendix A.

Information on referenced publications can be found in Chapter 5.

Chapter 1 Administration

1-1 Scope.

1-1.1

This standard establishes test procedures for evaluating the foam fire fighting equipment installed on rescue and fire fighting vehicles designed in accordance with the applicable portions of NFPA 414, *Standard for Aircraft Rescue and Fire Fighting Vehicles*.

1-2 Purpose.

1-2.1

The tests specified in this standard provide procedures for the evaluation of foam fire fighting equipment in the field to determine compliance with NFPA 414, *Standard for Aircraft Rescue and Fire Fighting Vehicles*, and NFPA 403, *Standard for Aircraft Rescue and Fire Fighting Services at Airports*.

1-3 Definitions.

Foam. An aggregation of small bubbles used to form an air-excluding, vapor-suppressing blanket over the surface of a flammable liquid fuel.

Foam, Alcohol-Resistant. Used for fighting fires involving water soluble materials or fuels that are destructive to other types of foams. Some alcohol-resistant foams may be capable of forming a vapor-suppressing aqueous film on the surface of hydrocarbon fuels.

Foam, Aqueous Film Forming (AFFF). A concentrated aqueous solution of one or more hydrocarbon or fluorochemical surfactants that forms a foam capable of producing a vapor-suppressing aqueous film on the surface of hydrocarbon fuels. The foam produced from AFFF concentrates is dry-chemical compatible and is therefore suitable for use in combination with that agent.

Foam Concentrate. A concentrated liquid foaming agent that is mixed with water and air in designated proportions to form foam.

Foam Drainage Time (Quarter Life). The time in minutes that it takes for 25 percent of the total liquid contained in the foam sample to drain out from the foam.

Foam Expansion. The ratio between the volume of foam produced and the volume of solution used in its production.

Foam, Film Forming Fluoroprotein (FFFP). A protein-based foam concentrate incorporating fluorinated surfactants that forms a foam capable of producing a vapor-suppressing aqueous film on the surface of hydrocarbon fuels. This foam may show an acceptable level of compatibility with dry chemicals, and may be suitable for use with those agents.

Foam, Fluoroprotein (FP). A protein-based foam concentrate, with added fluorochemical surfactants, that forms a foam showing a measurable degree of compatibility with dry chemical extinguishing agents and an increase in tolerance to contamination by fuel.

Foam Pattern. The ground area over which foam is distributed during the discharge of a foam-making device.

Foam, Protein (P). A protein-based foam concentrate that is stabilized with metal salts to make a fire-resistant foam blanket.

Foam Solution. The solution that results when foam concentrate and water are mixed in designated proportions prior to aerating to form foam.

Foam Stability. The degree to which a foam resists spontaneous collapse or degradation caused by external influences such as heat or chemical action.

Foam Weep. That portion of foam that is separated from the principal foam stream during discharge and falls at short range.

Heat Resistance. The property of a foam to withstand exposure to high heat fluxes without loss of stability.

Shall. Indicates a mandatory requirement.

Should. This term, as used in the Appendix, indicates a recommendation or that which is advised but not required.

Chapter 2 Rescue and Fire Fighting Vehicle Foam Production Performance Testing

2-1 Foam and Foam System Tests.

2-1.1

The expansion and 25 percent drainage time are the foam characteristics that shall be determined. Additionally, the foam concentration shall be determined, both as a test of the vehicle proportioning system, and to establish the legitimacy of the expansion and drainage data obtained. Foam distribution patterns shall be determined for use in calculating the area of fire that the vehicle is capable of controlling.

2-2 Turret Nozzles.

2-2.1

The foam distribution patterns shall meet the requirements of 2-15.6.3 for major RFF vehicles, 3-13.9.3 for rapid intervention vehicles, and 4-13.9.3 for combined agent vehicles of NFPA 414, *Standard for Aircraft Rescue and Fire Fighting Vehicles*, when tested as specified in Section 4-1 of this standard.

2-2.2

Foam samples shall be obtained by the methods given in 4-3.1.2 of this standard.

2-2.3

Foam samples shall be analyzed for expansion and drainage time using the method specified in Section 3-1 of this standard.

2-2.4

Foam samples shall be analyzed for concentration as specified in Section 3-2 of this standard.

2-3 Ground Sweep Nozzles.

2-3.1

The foam distribution patterns shall meet the requirements of 2-15.8.1 of NFPA 414, *Standard for Aircraft Rescue and Fire Fighting Vehicles*, when tested as specified in Section 4-2 of this standard.

2-3.2

Foam samples shall be obtained by the methods given in 4-3.1.2 of this standard.

2-3.3

Foam samples shall be analyzed for expansion and drainage time using the method specified in Section 3-1 of this standard.

2-3.4

Foam samples shall be analyzed for concentration as specified in Section 3-2 of this standard.

2-4 Hand Line Nozzles.

2-4.1

The foam distribution patterns shall meet the requirements of 2-15.7.3.3 for major RFF vehicles, 3-13.10.2.3 for rapid intervention vehicles, and 4-13.10.2.3 for combined agent vehicles of NFPA 414, *Standard for Aircraft Rescue and Fire Fighting Vehicles*, when tested as specified in Section 4-2 of this standard.

2-4.2

Foam samples shall be obtained by the methods given in 4-3.1.2 of this standard.

2-4.3

Foam samples shall be analyzed for expansion and drainage time using the method specified in Section 3-1 of this standard.

2-4.4

Foam samples shall be analyzed for concentration as specified in Section 3-2 of this standard.

2-5 Undertruck Nozzles.

2-5.1

The foam distribution pattern shall provide protection for the area beneath the vehicle.

2-5.2

Foam samples shall be collected and analyzed for concentration as specified in Section 3-2 of this standard.

Chapter 3 Performance Criteria

3-1 Expansion Ratio and Drainage Time Requirements.

Foams shall be tested as specified in 4-3.2 of this standard and shall meet at least the performance requirements specified in Table 3-1 of this chapter.

Table 3-1 Foam Quality Requirements

Foam Agents	Minimum Expansion Ratio	Minimum Solution 25% Drainage Time in Minutes
AFFF Air-Aspirated	5:1	2.25
FFFP Air-Aspirated	5:1	2.25
AFFF Non- Air-Aspirated	3:1	0.75
FFFP Non- Air-Aspirated	3:1	0.75
Protein	8:1	10
Fluoroprotein	6:1	10

3-2 Foam Solution Concentration.

3-2.1

Foam solution concentration shall be tested in accordance with Section 4-4 of this standard.

3-2.2*

For nominal 6 percent concentrates, the concentration shall be between 5.5 and 7.0 percent for turret and ground sweep nozzles, and between 5.5 and 8.0 percent for hand line and undertruck nozzles.

3-2.3

For nominal 3 percent concentrates, the concentration shall be between 2.8 and 3.5 percent for turret and ground sweep nozzles, and between 2.8 and 4.0 percent for hand line and undertruck nozzles.

Chapter 4 Test Methods and Calculations

4-1 Turret Ground Pattern Test.

4-1.1

Prior to the start of the tests, the water tank shall be full, the foam concentrate tank shall be full with the type of foam concentrate to be used during the actual emergencies, and the proportioner shall be set for normal fire fighting operation. For premixed systems, the tank shall be full with the premixed solution in the correct proportion for normal fire fighting operations.

4-1.2*

Discharge tests shall be conducted to establish the fire fighting foam discharge patterns produced and the maximum range attainable by the turret nozzle. The test shall be conducted under wind conditions of 5 mph or less. To determine maximum discharge range, the turret nozzles shall be tilted upward to form a 30-degree angle with the horizontal.

4-1.3

Foam shall be discharged onto a paved surface for a period of 30 seconds at the specified pressure, in both the straight stream and fully dispersed nozzle settings. Immediately after foam discharge has stopped, markers shall be placed around the outside perimeter to preserve the identity of the foam pattern as it fell on the ground. For purposes of defining the edge of the pattern, any foam of less than $^{1}/_{2}$ inch in depth shall be disregarded. Distances between markers shall be plotted on graph paper. The vertical axis shall show the reach, and the horizontal axis shall show the pattern width for each nozzle setting. The distance from the nozzle to the end of the effective foam pattern shall be measured and plotted on the graph paper.

4-2 Ground Sweep and Hand Line Nozzle Tests.

4-2.1

Ground sweep nozzles and hand line foam nozzles shall be discharged onto a paved surface for a period of 30 seconds.

4-2.2

Ground sweep nozzles shall be discharged from their fixed positions.

4-2.3

Hand line nozzles shall be held at their normal working height and tilted upward to form a 30-degree angle with the horizontal.

4-2.4

Markers shall be set out to denote the outline of the effective foam pattern and plotted, as described under the turret test in 4-1.3.

4-2.5

Patterns from both the straight stream and the fully dispersed nozzle settings shall be established, measured, and recorded.

4-3 Foam Tests.

4-3.1 General Requirements for All Test Methods.

4-3.1.1 The tests shall be conducted with the temperature of the water or foam solution in the range of 60°–80°F (16°–27°C).

4-3.1.2 The following corrections shall be applied to protective foams:

Expansion: If the solution temperature is higher than 70°F, no correction shall apply. If the temperature is lower than 70°F, 0.1 unit of expansion shall be added for each 3°F below 70°F.

Drainage Time: If the solution temperature is higher than 70°F, 0.1 minute shall be added for each 3°F above 70°F. If the solution temperature is lower than 70°F, 0.1 minute shall be subtracted for each 3°F lower than 70°F.

4-3.1.3 Foam samples selected for analysis shall be representative of the foam produced by the nozzle as it would be applied onto the fire hazard. This shall be accomplished by placing a foam sample collector in the center of the ground pattern as determined in the nozzle pattern test.

4-3.2 Test Method.

4-3.2.1 Foam Sampling Apparatus.

4-3.2.1.1 The object is to obtain a sample of foam that is typical of that to be applied to the burning fuel surface under anticipated fire conditions. The foam collector shall be constructed as specified in Figure 4-3.2.1.1.

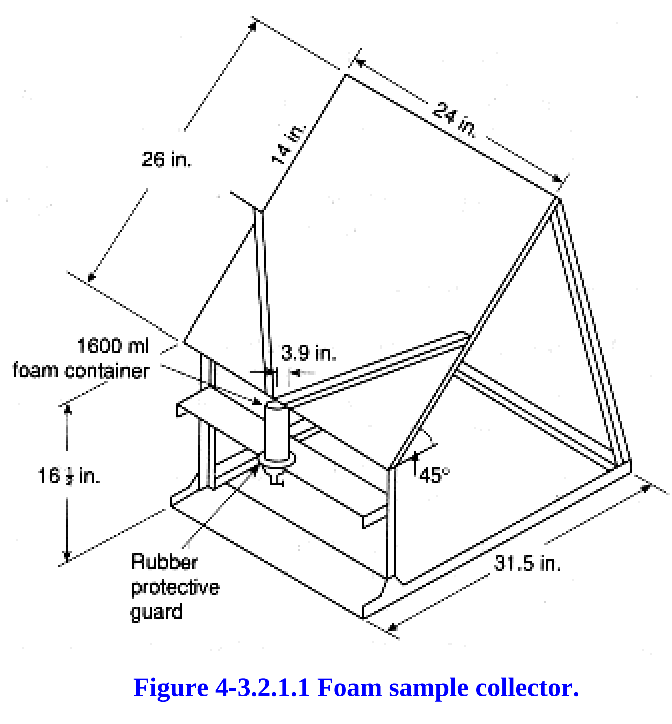


Figure 4-3.2.1.1 Foam sample collector.

4-3.2.1.2 The foam sample shall be collected in a cylindrical 1600-ml container. The foam sample container shall be constructed as specified in Figure 4-3.2.1.2.

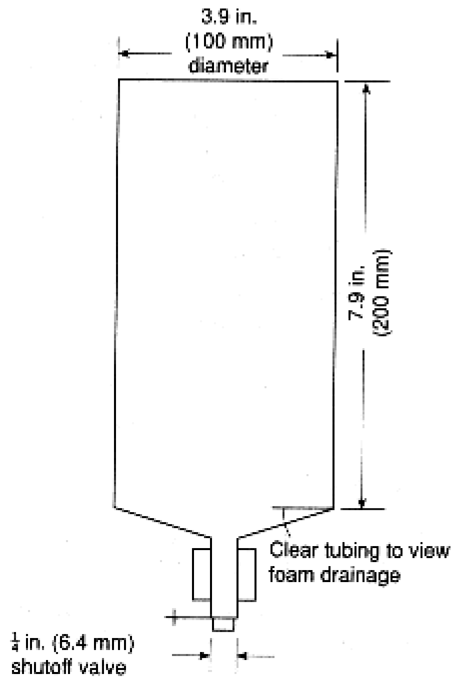


Figure 4-3.2.1.2 1600-ml foam sample container.

4-3.2.2 Test Procedure.

4-3.2.2.1 The empty weight of the foam sample container shall be recorded to the nearest gram on a balance having a maximum capacity sufficient to weigh the foam sample container, on a suitable support, and the foam sample. The foam sample collector shall then be located in the center of the discharge pattern determined in Section 4-1 of this standard. The foam sample container shall be positioned at the bottom of the foam collector so that the foam hitting the collector will flow into the container. The foam nozzle shall be aimed off the side of the foam collector, adjusted to its normal operating pressure, and then moved so as to discharge foam onto the foam sample collector. As soon as the foam sample container has been completely filled with foam, the discharge nozzle shall be shut off and the timing of the 25 percent drainage started.

4-3.2.2.2 The foam sample container shall be removed from the base of the foam collector, excess foam struck off the top of the foam container using a straight edge, and any remaining foam wiped from the outside surface of the container. The container shall then be placed on the balance. The total weight of the foam sample and container shall be determined to the nearest gram. The weight of the foam sample in the container shall be determined by subtracting the weight of the empty container from the weight of the container filled with the foam. The weight of the foam sample in grams shall be divided by four to obtain the equivalent 25 percent drainage volume in milliliters.

4-3.2.2.3 The foam sample container shall then be placed on a suitable support and a graduated cylinder placed below the drain spout. At 30-second intervals, the accumulated solution in the bottom of the foam sample container shall be drawn off into a graduated cylinder and the amount recorded. If the expected expansion ratio is more than 5:1, then a 100-ml graduated cylinder shall be used to collect the drainage, and if the expected expansion ratio is 5:1 or less, then a 250-ml graduated cylinder shall be used.

4-3.2.2.4* Foam samples shall be weighed to the nearest gram. The expansion of the foam shall be calculated by the following equation:

$$\text{Expansion: } = \frac{1600 \text{ ml}}{\text{full weight minus empty weight in grams}}$$

4-4 Foam Solution Concentration Determination.

4-4.1*

A hand-held refractometer or conductivity meter shall be used to measure the refractive index or conductivity of the solution, from which the solution concentration may be calculated. Special care shall be taken when determining the concentration of AFFFs by means of refractive index due to the very low refractive index exhibited by these products.

4-4.2

A calibration curve shall be prepared using the following apparatus:

(a) three 100-ml graduates

(b) one measuring pipette (10-ml capacity)

(c) one 100-ml beaker

(d) one 500-ml beaker.

(e)* one hand-held refractometer — American Optical Co. Model No. 10430 or equivalent; or one hand-held conductivity meter — Omega Model CDH-70 or equivalent.

4-4.3*

Using water and foam concentrate from the tanks of the vehicle to be tested, three standard solutions shall be made up by pipetting into three 100-ml graduated cylinders, volumes of foam concentrate in milliliters equal to:

(a) the nominal concentration of the foam concentrate

(b) $^{1}/_{3}$ more than the nominal concentration

(c) $^{1}/_{3}$ less than the nominal concentration.

The graduated cylinders shall then be filled to the 100-ml mark with the water. After thoroughly mixing, a refractive index reading shall be taken of each standard by placing a few drops of the solution on the refractometer prism, closing the cover plate, and observing the scale reading at the dark field intersection. Or, if using conductivity, the probe shall be dipped into the solution and the digital scale read. A plot shall be made on graph paper of the scale reading against the known foam solution concentrates and shall serve as a calibration curve for this particular series of foam tests.

4-4.4*

Portions of solution drained out during the previously described drainage test shall be used as a source of test sample for the concentration determination. Refractive index or conductivity readings of the unknown shall be compared to the calibration curve and the corresponding foam solution concentration read from the graph.

4-5 Report of Results of Tests.

4-5.1*

All test reports shall include a statement of the operating conditions, such as pressures, temperatures, wind velocities and direction in relation to vehicle position, and a full description of the materials and equipment used.

Chapter 5 Referenced Publications

5-1

The following documents or portions thereof are referenced within this standard and shall be considered part of the requirements of this document. The edition indicated for each reference is the current edition as of the date of the NFPA issuance of this document.

5-1.1 NFPA Publications.

National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.

NFPA 403, *Standard for Aircraft Rescue and Fire Fighting Services at Airports*, 1993 edition.

NFPA 414, *Standard for Aircraft Rescue and Fire Fighting Vehicles*, 1990 edition.

Appendix A Explanatory Material

This Appendix is not a part of the requirements of this NFPA document, but is included for information purposes only.

A-3-2.2

The amount of foam concentrate in the solution fed to the foam maker plays an important part, not only in the making of foam with the proper expansion and drainage rate, but also in making a fire-resistant foam. Therefore, it is essential that correct proportioning is maintained and that the concentration meets the required level even if the foam meets the minimum expansion and drainage time values at other levels of concentration.

A-4-1.2

See Figure A-4-1.2 on the following page.

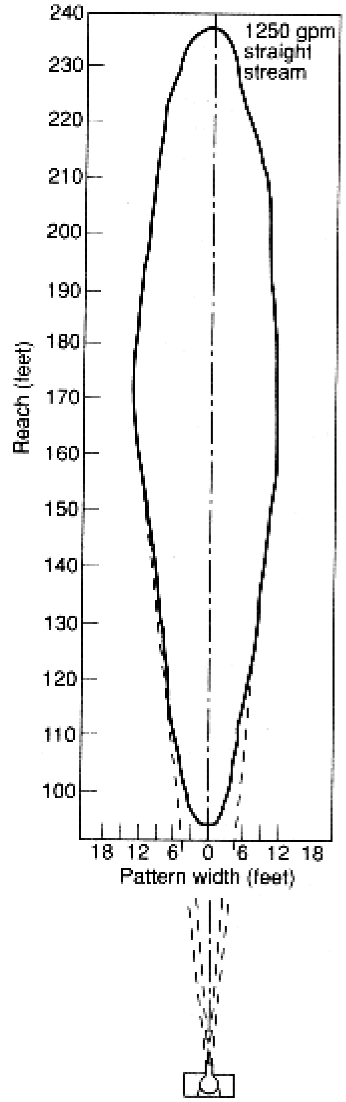


Figure A-4-1.2 Typical foam discharge pattern.

A-4-3.2.2.4 The following shows the calculation of expansion. The net weight of the foam sample (see drainage example) is assumed to be 200 g; therefore, the volume of foam solution contained in the 1600 ml foam sample is 200 ml.

$$\text{Expansion:} = \frac{\text{volume of foam}}{\text{volume of solution}} = \frac{1600\ \text{ml}}{200\ \text{ml}} = 8$$

A-4-4.1

The conductivity method is not recommended where seawater is used for making foam solution.

When the conductivity method is used and samples are to be stored and analyzed at some time other than during testing, clean glass containers should be used to store the samples.

Storage of solution in other types of containers (metal, low density polyethylene) may affect the conductivity reading over a period of time.

Care should be taken that conductivity measurements are made when the water and foam solution are at the same temperature. Small differences in temperature may substantially change conductivity measurements.

The recommended meter automatically compensates for different temperatures. If other meters are used, the instructions for the conductivity meter calibration and temperature compensation should be carefully followed.

A-4-4.2 (e) ATAGO Co. Ltd. Model No. N10, AO Model No. 10441, or equivalent showing 0-10 on the BRIX scale is recommended to enable low readings given by AFFF solutions to be read easily.

A-4-4.3

See Figures A-4-4.3(a), A-4-4.3(b), and A-4-4.3(c).

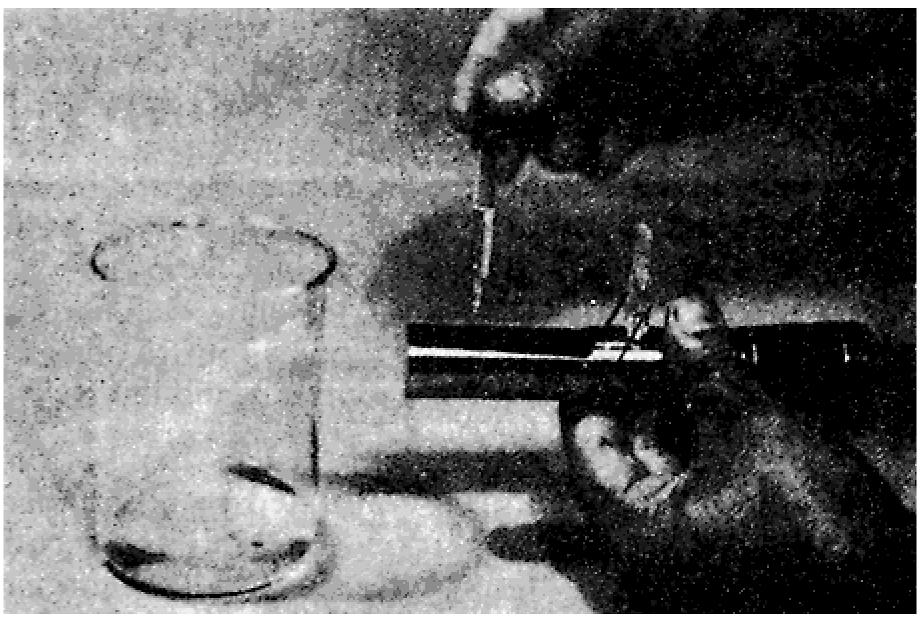


Figure A-4-4.3(a) The index of refraction is measured by placing a few drops of the solution to be tested on the prism of a refractometer and closing the cover plate. This is a typical refractometer suitable for this purpose.

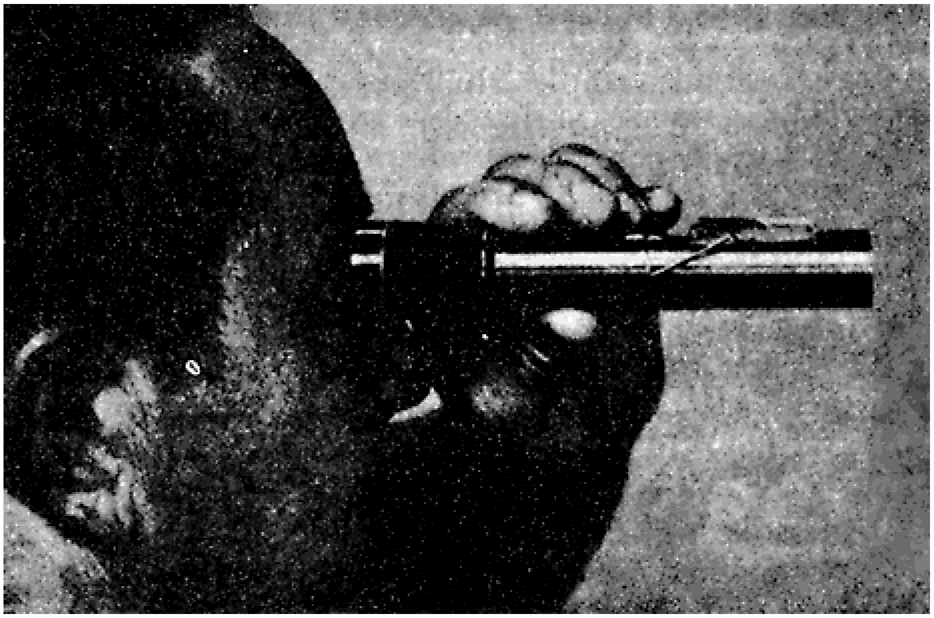


Figure A-4-4.3(b) When this type refractometer is held up to a light source, a reading is taken where the dark field intersects the numbered scale.

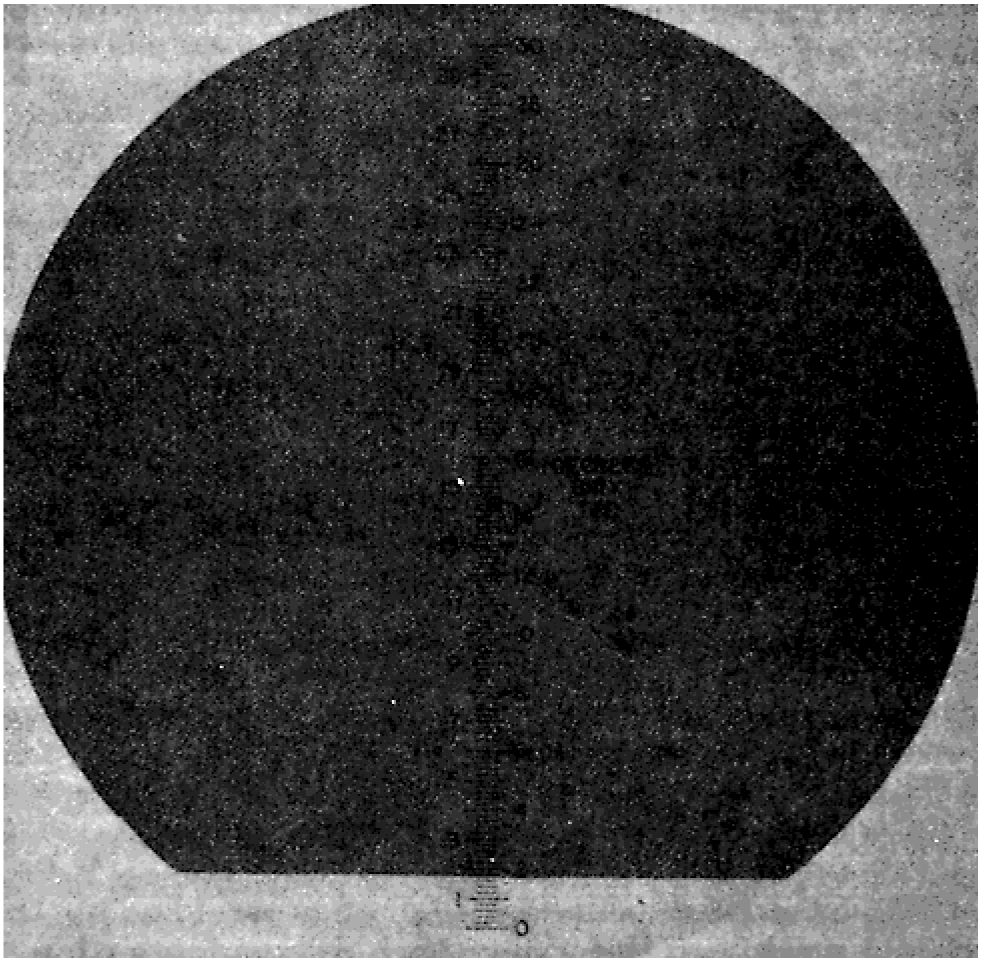
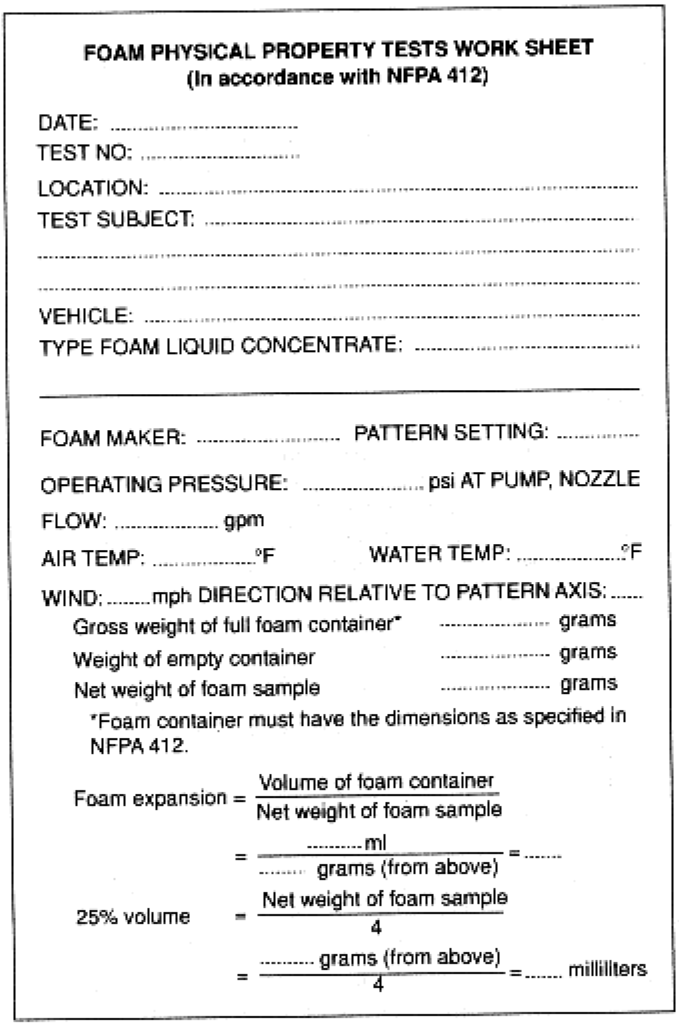


Figure A-4-4.3(c) This illustrates the field of view looking into the refractometer illustrated in Figures A-4-4.3 (a) and A-4-4.3 (b) containing a 6 percent AFFF solution. The dark intersects the scale at 1.7 and this value is recorded as the reading for a 6 percent concentration

A-4-4.4

Because of the high sensitivity of the conductivity meter, it is necessary to collect a larger sample of drainage before making the determination. This will allow for the variation in conductivity of the drained liquid caused by small changes in the chemical composition of AFFF solution as it drains out over a period of time.

A-4-5.1 Foam Physical Property Tests Work Sheets



FOAM PHYSICAL PROPERTY TESTS WORK SHEET
(In accordance with NFPA 412)

DATE: ....
TEST NO: ....
LOCATION: ....
TEST SUBJECT: ....
....
....
VEHICLE: ....
TYPE FOAM LIQUID CONCENTRATE: ....

FOAM MAKER: .... PATTERN SETTING: ....
OPERATING PRESSURE: .... psi AT PUMP, NOZZLE
FLOW: .... gpm
AIR TEMP: ....°F WATER TEMP: ....°F
WIND: ....mph DIRECTION RELATIVE TO PATTERN AXIS: ......

Gross weight of full foam container* .... grams
Weight of empty container .... grams
Net weight of foam sample .... grams

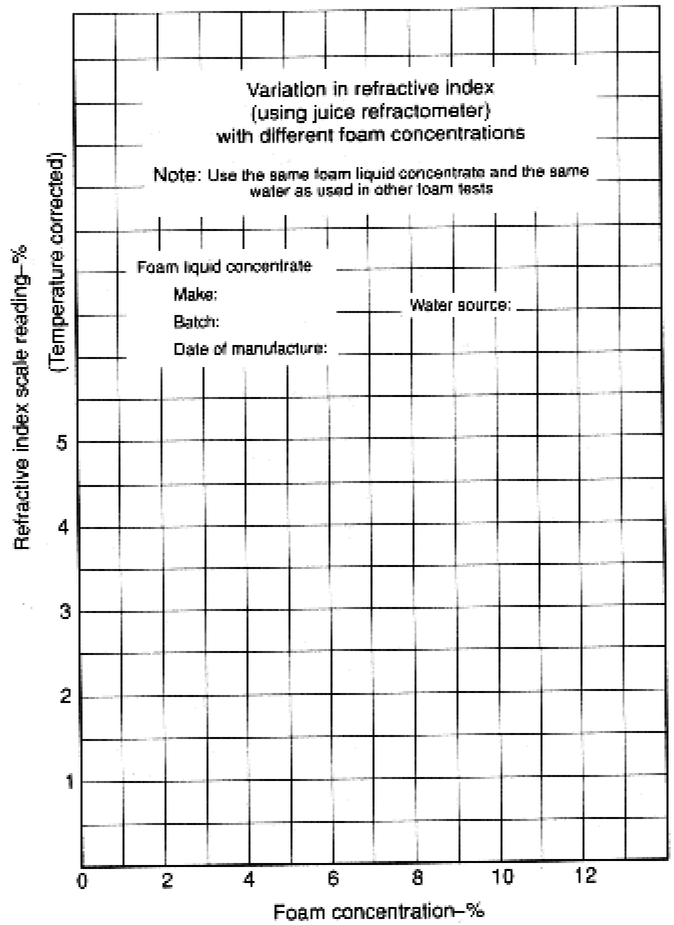
*Foam container must have the dimensions as specified in NFPA 412.

Foam expansion = Volume of foam container / Net weight of foam sample

= ....ml / .... grams (from above) = ...

25% volume = Net weight of foam sample / 4

= .... grams (from above) / 4 = ... milliliters



Appendix B

This Appendix is not a part of the requirements of this NFPA document, but is included for information purposes only.

B-1 Foam Extinguishing System Capability.

B-1.1

The following is a suggested method for evaluating the basic extinguishing capability of the foam fire fighting system.

B-1.2 Basic Extinguishing Capability.

B-1.2.1 Foam performance is judged on two criteria: (1) ability for quick knockdown of flames, and (2) ability to keep fuel area secure against re-ignition. To obtain meaningful information, it is necessary that the foam be applied at low rates per square foot of fuel surface. This will represent the performance to be expected when the system is pushed to its ultimate capability on a large fire. High application rates will overwhelm the fire and obscure any possible shortcomings. Fire tests sufficiently large to challenge the foam equipment are very costly and difficult to conduct without creating undue environmental problems. Therefore, an attempt is made in this standard to devise a restricted but still significant procedure.

B-1.2.2 A foam vehicle user might utilize the basic test procedure in several ways. For example, it might be desired to establish the minimum rate of foam application at which a fire can be extinguished. By using this rate and the time for extinguishment, the volume of water required to extinguish one unit fire area (square foot or square meter), and the maximum fire area the vehicle is capable of extinguishing, can be calculated. It should be kept in mind, however, that the most efficient use of water lends to long extinguishing times. In practice, a high application rate is required because it gives the most rapid knockdown of flame, although it will be less efficient in terms of agent consumed. Operation of the turret to achieve complete extinguishment also wastes water. Generally, after the fire has been 90 percent extinguished, it is better to shut down the turret and complete the extinguishment by application of foam from handlines or by the application of one of the complementary agents.

B-1.2.3 A user might desire to compare the system used on two different fuels or under several different weather conditions such as high winds, heavy rain, or extreme low temperatures, or with obstacles within the fire area. In this type of testing, care must be taken to change only one variable at a time. All other conditions must remain the same.

B-1.2.4 A user might desire to check the foam used against its “as purchased” condition. Here the tests must be conducted under the same conditions as those prevailing during the original tests.

B-1.3 Turret or Hand Line Extinguishing Tests.

B-1.3.1 The exact size of the fire to be used is not critical; however, it should be not less than 100 ft^2 (10 ft × 10 ft) in area. Large-scale testing has shown that larger fire areas do not necessarily require higher application rates or greater quantities of agent (foam) per unit area.

B-1.3.2 The choice of fuel is optional depending on the data desired. Gasolines are normally the most difficult fuels to extinguish, a Jet A (JP-5) the easiest. Jet B (JP-4) is a variable fuel without a definitive flash point.

B-1.3.3 Water may be used to level a large pit to ensure a level fuel area, and bare ground should be presoaked to prevent the loss of fuel. The amount of fuel to be used is partially dependent on the length of preburn to be allowed. With preburn times of 1 min, at least 1 gal of fuel for each 2 ft^2 of area should be used.

B-1.3.4 Local clean air regulations might dictate the length of preburn as this is the period of greatest smoke generation.

B-1.3.5 Establishing and maintaining the desired rate of foam application will require some work and practice prior to the conducting of the fire test. The object is to sweep the turret or nozzle back and forth over the fire area at an even rate in order to apply the foam at the desired gallons per minute (gpm) per square foot.

B-1.3.6 The actual rate is checked by placing 1 ft^2 (or other known convenient size of known area) shallow pans near the edges of the fire area. After the foam discharge pattern has been swept back and forth over the fire area and pans for a measured period of time, the stream is shut off, the weight of the contents of each pan determined, and the application rate calculated. If the rate was too high, a faster rate and wider angle of sweep will be required and vice versa. Once the proper technique has been worked out, the fire is extinguished in the same manner. The pans can be used during the fire test to verify the application rate. NFPA 403 requires a rate of 0.13 gpm per square foot for AFFF, 0.20 gpm per square foot for protein foam, and 0.18 gpm per square foot for fluoroprotein foam.

B-1.3.7 The following calculations are typical of those used in the determination of the basic extinguishing capability of an aircraft rescue and fire fighting vehicle of 1000 gal water capacity:

Gross weight of pan with collected foam	412 oz
Empty weight of pan	350

Net weight of foam sample	62 oz

$$\text{Water collected} = \frac{\text{foam wt. oz}}{133.3} = \frac{62}{133.3} = 0.465 \text{ gallons}$$

$$\text{Total water applied} = \frac{\text{water collected, gal}}{\text{area of pan, ft}^2} = \frac{0.465}{3.5}$$

$$= 0.133 \text{ gal/ft}^2$$

$$\text{Basic extinguishing capability} = \frac{1000 \text{ gal}}{0.133 \text{ gal/ft}^2}$$

$$= 7600 \text{ ft}^2\text{/1000 gal water}$$

B-1.4 Burnback Test.

B-1.4.1 The resistance of the foam blanket to the fire is important. Wind plays a big role in the determination of this property and repeat results are difficult to obtain with an outdoor test. Another factor, but one easier to control, is the size of the fire area at the start of re-ignition. To standardize this, a short section of stovepipe 12 in. in diameter is dropped into the foam blanket like a cookie cutter. The foam is removed from the inside, and the fuel surface is ignited and allowed to burn for one minute before the stovepipe is removed. The rate of enlargement of the fire is then observed. A long period of confinement is desired. The delay period after end of foam application and start of re-ignition may be varied, but for comparative tests, it must be kept constant.

B-1.4.2 Burnback resistance is related to the amount of foam that has been applied to the fire. A burnback test on a fire area that has been extinguished with a minimum application of foam will not afford a high level of protection.

B-1.4.3 To compare the degree of burnback protection of different agents and depths of foam, and to familiarize crew with the degree of protection afforded, repeated tests using varied delays between end of foam application and start of re-ignition are suggested.

Appendix C Referenced Publications

C-1

The following documents or portions thereof are referenced within this standard for informational purposes only and thus are not considered part of the requirements of this document. The edition indicated for each reference is the current edition as of the date of the NFPA issuance of this document.

C-1.1 NFPA Publication.

National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.

NFPA 403, *Standard for Aircraft Rescue and Fire Fighting Services at Airports*, 1993 edition.

NFPA 414

1995 Edition

Standard for Aircraft Rescue and Fire-Fighting Vehicles

1995 Edition

This edition of NFPA 414, *Standard for Aircraft Rescue and Fire-Fighting Vehicles*, was prepared by the Technical Committee on Aircraft Rescue and Fire Fighting and acted on by the National Fire Protection Association, Inc., at its Annual Meeting held May 22-25, 1995, in Denver, CO. It was issued by the Standards Council on July 21, 1995, with an effective date of August 11, 1995, and supersedes all previous editions.

This edition of NFPA 414 was approved as an American National Standard on August 11, 1995.

Changes other than editorial are indicated by a vertical rule in the margin of the pages on which they appear. These lines are included as an aid to the user in identifying changes from the previous edition.

Origin and Development of NFPA 414

In 1960, a tentative edition of this standard was adopted by the Association. The original document was further revised in 1962, 1963, 1964, 1965, 1967, 1968, 1969, 1970, 1975, and 1978.

In 1984, the standard was revised completely to identify three types of vehicles and to make the document easier to use. The text also was rewritten to conform with the NFPA *Manual of Style*.

The standard was revised again in 1990, and a chapter was added to provide a test method to verify the design requirements.

Notable revisions to the 1995 edition include the removal of requirements for a separate category of rapid intervention vehicle.

Technical Committee on Aircraft Rescue and Fire Fighting

John F. Rooney, *Chair*
Tucson, AZ

James F. O'Regan, *Vice Chair*
Westboro, MA

Robert J. Donahue, *Secretary*
Massport Fire Dept., Logan Int'l Airport, MA

Brian Boucher, Canadian Air Line Pilots Assn., ON, Canada
Rep. Canadian Air Line Pilots Assn.

Booker T. Burley, Hartsfield Atlanta Int'l Airport, GA

Ralph Colet, John Russo Industrial Inc, CA

Robert L. Darwin, U.S. Dept. of the Navy, DC

Charlie L. Duncan, Atlanta Fire Dept., Atlanta Airport, GA

Fred B. Goodnight, Amerex Corp., AL
Rep. Fire Equipment Mfrs. Assn., Inc.

B. V. Hewes, Airport Safety Services, GA

Paul O. Huston, Paul O. Huston, PE & Assoc., AL

D. Steve Kiernan, Chubb Nat'l Foam, Inc., PA

L. M. Krasner, Factory Mutual Research Corp., MA

Dave Lenz, Oshkosh Truck Corp., WI

Thomas J. Lett, Albuquerque Fire/Safety Assn. Inc., NM
Rep. NFPA Fire Service Section

Daniel A. Nommensen, Emergency One, Inc., FL

John J. O'Sullivan, British Airways, England

Davis R. Parsons, Los Angeles City Fire Dept., CA

Gaetan Perron, Dept. of Nat'l Defence, ON, Canada

Robert G. Relyea, ARFF Working Group, TX

Robert E. Reyff, U.S. Air Force, FL

Paul R. Robinson, Kennesaw, GA
Rep. Air Line Pilots Assn.

Joseph L. Scheffey, Hughes Assoc. Inc., MD

John M. Schuster, 3M Co., MN

John X. Stefanki, John X Stefanki Inc., CA

William J. Wenzel, Schenectady, NY
Rep. Walter Truck Corp.

Ronald O. Wikander, Lockheed Aeronautical Systems Co., GA

Larry E. Williams, Emergency Response Training Academy, Inc., AR

Joseph A. Wright, Federal Aviation Administration Tech Ctr., NJ

Alternates

D. L. J. Dunbar, Simon Gloster Saro Ltd, England
(Vot. Alt. to SGSL Rep.)

Frank M. E. Hughes, British Airways, England
(Alt. to J. J. O'Sullivan)

Thomas E. McMaster, Los Angeles City Fire Dept., CA
(Alt. to D. R. Parsons)

Richard E. Ottman, 3M Co., MN
(Alt. to J. M. Schuster)

William S. Weeks, Air Line Pilots Assn., NC
(Alt. to P. R. Robinson)

Nonvoting

John Cedric Black, BAA plc, England

Derek K. G. Dodwell, Civil Aviation Authority, England

Gary Hammack, U.S. Nat'l Transportation Safety Board, DC
(Alt. to L. D. Roman)

John E. Lodge, Lodge Fire Protection Consultancy Ltd, England
(Member Emeritus)

Lawrence D. Roman, U.S. Nat'l Transportation Safety Board, DC

David F. Short, Carmichael Int'l Ltd, England

Paul J. Lindsay, Transport Canada, ON, Canada
(Alt. to B. Valois)

Richard M. Radford, The Fire Service College, England

Bernard Valois, Transport Canada, ON, Canada

Mark T. Conroy, NFPA Staff Liaison

This list represents the membership at the time the Committee was balloted on the text of this edition. Since that time, changes in the membership may have occurred.

NOTE: Membership on a Committee shall not in and of itself constitute an endorsement of the Association or any document developed by the Committee on which the member serves.

Committee Scope: This Committee shall have primary responsibility for documents on aircraft rescue and fire-fighting services and equipment, for procedures for handling aircraft fire emergencies, and for specialized vehicles used to perform these functions at airports, with particular emphasis on saving lives and reducing injuries coincident with aircraft fires following impact or aircraft ground fires. This Committee also shall have responsibility for documents on aircraft fire investigation procedures as an aid to accident prevention and the saving of lives in future aircraft accidents involving fire.

Standard for
Aircraft Rescue and Fire-Fighting Vehicles

1995 Edition

NOTICE: An asterisk (*) following the number or letter designating a paragraph indicates explanatory material on that paragraph in Appendix A.
Information on referenced publications can be found in Chapter 5 and Appendix E.

Chapter 1 Administration

1-1 Scope.

1-1.1*

This standard specifies the optimum design, performance, and acceptance criteria for aircraft rescue and fire-fighting vehicles intended to carry rescue and fire-fighting equipment for rescuing occupants and combating fires in aircraft on, or in the vicinity of, an airport.

1-1.2

This standard shall cover three types of vehicles as follows:

(a) Major vehicles;

(b) Rapid intervention vehicles; and

(c) Combined agent vehicles.

1-1.3

Vehicles without wheels, such as track, amphibious, or air-cushion types, are not covered by this standard.

1-1.4

The design criteria for the standard vehicles described by this document shall consider temperature extremes ranging from 32°F to 110°F (0°C to 43.3°C). For cold weather operation where temperatures periodically range from -40°F to 32°F (-40°C to 0°C) or lower, some type of winterization system shall be specified by the purchaser.

1-2 Purpose.

1-2.1

The purpose of this standard is to specify features and components that, when assembled, produce an efficient and capable fire-fighting vehicle for both on-pavement and off-pavement performance. Off-pavement capability is important to ensure timely and effective response of these vehicles to aircraft accident sites located off paved surfaces. Fire-fighting capabilities are considered to be optimum for the proper performance of these vehicles.

1-2.2

It is not the purpose of this standard to serve as a detailed purchase specification. Drafting of complete specifications for bidding purposes is the responsibility of the purchaser.

1-3* Definitions.

AFFF. See Aqueous Film-Forming Foam Concentrate.

Aggressive Tire Tread. Tread designed to provide maximum traction for all types of surfaces. These include sand, mud, snow, ice, and hard surfaces, wet or dry.

Air-Cooled Engine. An engine in which the heat produced by the cylinder walls is absorbed directly by the atmosphere rather than by being absorbed by a liquid coolant that acts only as a vehicle for transferring the heat from the engine to a radiator.

Air-Mechanical Brakes. Brakes in which the force from an individual air chamber is applied directly to the friction surfaces through a mechanical linkage.

Air-Over-Hydraulic Brakes. Brakes in which the force of a master air cylinder is applied to the friction surfaces through an intervening hydraulic system.

All-Wheel Drive. A vehicle that drives on all wheels such as described in (b), (d), and (e) under the definition of Vehicle Types.

Ambient Temperature. The average temperature of the environment surrounding a vehicle.

Angle of Approach. The measure of the steepest ramp that a fully loaded vehicle can approach. It is determined by the horizontal ground line and the line tangent to the loaded radius of the front tire extended forward to that fixed point on the vehicle that forms the smallest angle.

Angle of Departure. The measure of the steepest ramp from which the fully loaded vehicle can depart. It is determined by the horizontal ground line and the line tangent to the loaded radius of the rear tire extended rearward to that fixed point on the vehicle that forms the smallest angle.

Approved.* Acceptable to the authority having jurisdiction.

Aqueous Film-Forming Foam (AFFF) Concentrate. A concentrated aqueous solution of fluorinated surfactant(s) and foam stabilizers that is capable of producing an aqueous fluorocarbon film on the surface of hydrocarbon fuels to suppress vaporization.

Authority Having Jurisdiction.* The organization, office, or individual responsible for approving equipment, an installation, or a procedure.

Automatic Locking Differential. A type of nonslip differential that operates automatically.

Axle Tread. The distance between the center of two tires or wheels on one axle. Where dual tires and wheels are used at each end of an axle, the tread is measured as the distance between centers of the pairs of tires or wheels.

Bogie. A combination of two axles used to support the end of a vehicle; therefore, in a 6 × 6 vehicle, there are two axles at the rear of the vehicle to support the weight on the rear. This two-axle combination is called a “rear bogie.” With an 8 × 8 vehicle, there are two axles in the front and two axles in the rear; therefore, there is a front bogie and a rear bogie.

Center of Gravity. The point within a vehicle at which all of its weight can be considered to be concentrated. Where a vehicle is tipped to such a degree that a vertical line passing through the center of gravity falls on the ground outside the tire track, it is unstable and can turn over.

Chassis. The assembled frame, engine, drive train, and tires of a vehicle.

Component Manufacturer’s Certification. A signed application approval furnished by the component manufacturer that certifies the following:

(a) The component is approved as being properly installed or applied, or both, in the vehicle for its intended use; or

(b) The component complies with the respective construction criteria required by the standard.

Cooling Preheater Device. A device for heating the engine coolant so that the engine is maintained at a constant temperature. It usually consists of a coolant jacket and an electric heating element. The engine coolant flows through the preheater jacket and is heated by the heating element, which obtains its power from an outside source, thereby maintaining the engine coolant at a constant temperature for fast starting.

Dry Nitrogen, Dry Air. Nitrogen or air that has a dew point of -60°F (-51°C) or lower.

Extendable Turret. A device, permanently mounted with a power-operated boom or booms, designed to supply a large-capacity, mobile, elevatable water stream or other fire-extinguishing agents, or both. The operator, while at the scene of the fire, has the ability to reposition the primary turret and attachments to a location that enhances the visibility of and access to hard to reach areas, thus providing the opportunity to utilize fire-fighting agents most effectively.

Fluid Coupling. A turbine-like device that transmits power solely through the action of a fluid in a closed circuit without direct mechanical connection between input and output shafts and without producing torque multiplication.

Fluoroprotein Foam Concentrate. A protein foam concentrate incorporating one or more fluorochemical surfactants to enhance its tolerance to fuel contamination.

Foam Expansion. The ratio between the volume of foam produced and the volume of solution used in its production.

Foam-Liquid Concentrate Percentage. The percentage of foam-liquid concentrate in solution with water.

Fully Loaded Vehicle. A fully loaded vehicle shall consist of the fully assembled vehicle, complete with a full compliment of crew, fuel, and fire-fighting agents. The crew allowance shall be 175 lb (79.3 kg) per seating position. Unless otherwise specified, the equipment allowance shall be 250 lb (113.3 kg) per storage compartment up to a maximum of 1000 lb (453.6 kg). Where the customer specifications require that more equipment shall be carried, the actual weight of the equipment shall be included.

In-Service Condition. A state or condition of readiness for intended duty; usually an emergency vehicle properly serviced with all equipment properly loaded and ready for immediate response.

Intended Airport Service.* All aspects of aircraft rescue and fire-fighting services as provided by this standard.

Interaxle Clearance Angle (Ramp Angle). The measure of the ability of a fully loaded vehicle to negotiate a ramp without encountering interference between the vehicle and the ramp between any two axles. It shall be determined by the horizontal ground line and whichever of the following lines forms the smaller angle:

(a) The line tangent to the loaded radius of the front tire extended rearward to that fixed point on the vehicle, ahead of a vertical line midway between the two axles, that determines the smallest angle;

(b) The line tangent to the loaded radius of the rear tire extended forward to that fixed point on the vehicle, behind a vertical line midway between the two axles, that determines the smallest angle.

Interaxle Differential. A differential in the line of drive between any two axles.

Lightweight Construction. The use of nonferrous metals or plastics or a reduction in weight by the use of advanced engineering practices resulting in a weight saving without sacrifice of strength or efficiency.

Listed.* Equipment or materials included in a list published by an organization acceptable to the authority having jurisdiction and concerned with product evaluation that maintains periodic inspection of production of listed equipment or materials and whose listing states either that the equipment or material meets appropriate standards or has been tested and found suitable for use in a specified manner.

May. This term is used to state a permissive use or an alternative method to a specified requirement.

No-Load Condition. The status of an engine with standard accessories operating without an imposed load, with the vehicle drive clutches and any special accessory clutches in a disengaged or neutral condition.

Off-Pavement Performance. A vehicle's ability to perform or operate on other than paved surfaces. "Other than paved surfaces" includes dirt roads and trails and open cross-country of all kinds. This ability sometimes is referred to as off-road mobility or cross-country mobility. All of these terms are synonymous.

Operational Tests. An all-vehicle test conducted by the manufacturer to ensure that each vehicle is fully operational when it is delivered and to ensure that the original level of performance of the prototype vehicle has been maintained.

Overall Height, Length, and Width. The dimensions determined with the vehicle fully loaded and equipped, unless otherwise specified. These dimensions shall include all fixed protrusions that could in any way hinder the passage of the vehicle. Dimensions that include a movable protrusion shall be determined with the protrusion in its normally stored position.

Percent Grade. The ratio of the change in elevation to the horizontal distance traveled multiplied by 100. A change in elevation of 50 ft (15.2 m) over a horizontal distance of 50 ft (15.2 m) is equivalent to a grade of 100 percent.

Power-Assist Steering. A system using hydraulic or air power to aid in the steering assist. This system is supplementary to the mechanical system in order to maintain steering ability in the event of power failure.

Protein Foam Concentrate. A concentrate consisting primarily of products from a protein hydrolysate, plus stabilizing additives and inhibitors to protect against freezing, to prevent corrosion of equipment and containers, to resist bacterial decomposition, to control viscosity, and otherwise to ensure readiness for use under emergency conditions.

Prototype Vehicle. The first vehicle of a unique vehicle configuration built to establish its performance capability and the performance capability of all subsequent vehicles manufactured from its drawings and parts list. A given chassis, body, and fire-fighting system and fully loaded weight condition shall constitute a vehicle configuration. Product improvements and customer options shall negate previously conducted prototype tests only if they substantially affect a performance factor.

Radio Suppression. Suppression of the ignition and electrical system noises that normally interfere with radio transmission and reception.

Reserve Capacity Rating. The number of minutes a new, fully charged battery at 80°F (26.7°C) can be discharged at 25 amperes while maintaining 1.75 volts per cell or higher.

Rubber-Gasketed Fitting. A device for providing a leakproof connection between two pieces of pipe while allowing moderate movement of one pipe relative to the other. It incorporates a rubber seal held in place by a two-piece clamp that also engages annular grooves near the end of each pipe to prevent pullout under pressure.

Seat Belt. A two-point lap belt, a three-point lap/shoulder belt, or a four-point lap/shoulder harness for vehicle occupants designed to limit their movement in the event of an accident, rapid acceleration, or rapid deceleration by safely securing the individual to a vehicle while in a seated position.

Shall. Indicates a mandatory requirement.

Should. Indicates a recommendation or that which is advised but not required.

Steering Drive Ends. Steering drive ends or stub shafts are in the front wheel spindle in a driving steering axle as used at the front of an all-wheel drive vehicle. The universal joint that allows steering while transmitting power is supported by the steering drive end at its inner end, and the outer end is connected to the wheel hub through a driving flange.

Ton. Weight equivalent to 2000 lb (906 kg).

Torque Converter. A device that is similar to a fluid coupling but that produces, by means of additional turbine blades, variable torque multiplication.

Twenty-Five (25) Percent Drainage Time. The time in minutes that it takes for 25 percent of the total liquid contained in the foam collected in a specified manner to drain. A method of measuring drainage time is provided in NFPA 412, *Standard for Evaluating Aircraft Rescue and Fire Fighting Foam Equipment*.

Underbody Clearance Dimensions. The dimensions determined with the vehicle fully loaded and fully equipped, unless otherwise specified. These dimensions shall include all components of the vehicle, except those that are part of the axle assemblies, that could hinder the passage of the vehicle.

Unitized Rigid Body and Frame Structure. A structure in which parts that generally comprise a separate body are integrated with the chassis frame to form a single, rigid, load-carrying structure.

Unsprung Weight. The total weight of all vehicle components that are not supported completely by the suspension system.

Vehicle Types. Vehicle types are designed as 4 × 2, 4 × 4, 6 × 4, 6 × 6, and 8 × 8. These designations are used to indicate the number of wheels on the vehicle and the number of wheels that propel or drive the vehicle. The term “wheel” in this designation is interpreted to mean either a single tire or a set of dual tires operating as one tire. The first number is the number of wheels, the second number is the number of driving wheels, therefore:

(a) A 4 × 2 vehicle has four wheels and drives on two wheels.

(b) A 4 × 4 vehicle has four wheels and drives on all four wheels.

(c) A 6 × 4 vehicle has six wheels and drives on four wheels.

(d) A 6 × 6 vehicle has six wheels and drives on all six wheels.

(e) An 8 × 8 vehicle has eight wheels and drives on all eight wheels.

Wall-to-Wall Turning Diameter. A measurement of the space that completely contains a vehicle as it is being turned. It is, therefore, the diameter of the smallest circle that can be described by the outermost point on the vehicle as it negotiates a 360-degree turn to the right or left.

Weatherproof. Sufficiently protected to prevent the penetration of rain, snow, and wind-driven sand, dirt, or dust under all operating conditions. This term is not intended to describe items that are watertight or submersible.

Weathertight. Having sufficient compartment closure to prevent the penetration of rain, snow, and wind-driven sand, dirt, or dust under all operating conditions. This term is not intended to describe items that are watertight or submersible.

Weight Scale Measurement. The accurate measurement of vehicle weight by means of a scale to verify or check a stated or estimated weight.

1-4 Requirements for All Aircraft Rescue and Fire-Fighting Vehicles — Responsibility of Contractors/Suppliers.

1-4.1*

The aircraft rescue and fire-fighting vehicle manufacturer shall assume responsibility for the design, construction, and performance of all component parts of the complete vehicle, even if major portions are subcontracted, and shall certify that the completed vehicle meets the requirements of this standard.

1-4.2

The manufacturer shall supply at time of delivery at least two complete copies of the following manuals:

(a) Operator’s manual;

(b) Service manual;

(c) Parts manual.

These manuals shall cover the entire vehicle and shall be in accordance with 1-4.2.1 through 1-4.2.3.2.

1-4.2.1 Operator's Manual. Operating instructions shall include all information required for operation of the vehicle, vehicle components, fire-fighting systems, and integral vehicular options. The location and function of all controls and instruments shall be covered by illustrations and descriptions. These instructions, as a minimum, also shall include the following:

(a) A complete description of the vehicle and special equipment;

(b) Preparation for use of the vehicle upon receipt;

(c) Daily maintenance and mission readiness checks to be performed by the operator;

(d) Periodic operator inspection.

1-4.2.2 Service Manual. The repair and overhaul instructions shall be factual, specific, concise, and clearly worded. The instructions shall cover such typical maintenance and repair operations as troubleshooting, adjustment procedures, minor and major repairs and overhaul, removal and replacement of units, assemblies and subassemblies, and complete instructions for disassembly and reassembly of components. The instructions also shall include data that include tolerances, specifications, and capacities. Illustrations, wiring diagrams, and exploded views shall be used to clarify text and shall appear as close to the related text as possible. Special tools needed for the repair and overhaul of the equipment shall be specified and illustrated. The service manual shall contain a suitable index.

1-4.2.3 Parts Manual. The parts list shall include illustrations and exploded views necessary for the proper identification of all parts, assemblies, and subassemblies. Assemblies or components shall be shown in illustrations and shall be identified by reference numbers that correspond to the reference numbers in the parts list. The size, thread dimensions, and special characteristics shall be given on all nonstandard nuts, bolts, washers, grease fittings, and similar items. The parts identification manual shall provide the description and quantity of each item used per vehicle. The parts identification manual shall contain a numerical index.

1-4.2.3.1 The vehicle manufacturer shall ensure the purchaser that parts critical to the mission of the vehicle are shipped within 48 hours. The original equipment manufacturers shall be disclosed to the owner if the vendor is unable to supply the necessary parts within this time frame to allow local purchase of an equivalent part.

1-4.2.3.2 A qualified and responsible representative of the contractor shall instruct personnel specified by the purchaser in the operation, care, and maintenance of the vehicle delivered. The purchasers shall specify provisions for training, including the location and duration, and shall agree on suitable training aids such as video tapes and training manuals.

1-4.3 Metal Finish.

1-4.3.1 All exposed ferrous metal surfaces that are not plated or of stainless steel or that are not otherwise treated to resist corrosion shall be cleaned thoroughly and prepared and shall be painted in the color(s) specified by the purchaser. If nonferrous body components are furnished, the purchaser shall specify which surfaces are to be painted. The paint, including the primer, shall be applied in accordance with the paint manufacturer's recommendation.

1-4.3.1.1 Paint finish shall be selected for maximum visibility and shall be resistant to damage from fire-fighting agents.

1-4.3.1.2 Dissimilar metals shall not be in contact with each other. Metal plating or metal spraying of metals of dissimilar base to provide electromotively compatible abutting surfaces shall be permitted. The use of dissimilar metals separated by suitable insulating material shall be permitted.

Exception: In systems where bridging of insulation materials by an electrically conductive fluid can occur, dissimilar metals shall not be permitted.

1-4.3.1.3 Materials that deteriorate when exposed to sunlight, weather, or operational conditions normally encountered during service shall not be used or shall have a means of protection against such deterioration that does not prevent compliance with performance requirements.

1-4.3.1.4 Protective coatings that chip, crack, or scale with age or extremes of climatic conditions or when exposed to heat shall not be used.

1-4.3.1.5 The use of proven, nonmetallic materials in lieu of metal shall be permitted, provided such use contributes to reduced weight, lower cost, or less maintenance and there is no degradation in performance or increase in long-term operations and maintenance costs.

1-4.4 Lettering, Numbering, and Striping.

1-4.4.1 Vehicle numbering, lettering, and minimum 8-in. (0.2-m) wide reflective striping shall be provided in accordance with ASTM D4956, *Standard Specification for Retroreflective Sheeting for Traffic Control*. Striping shall be placed horizontally on the sides of the vehicle below the body centerline. Vehicles shall display an identification number on each side and roof. Side numbers shall be a minimum of 16 in. (0.4 m) in height. Roof numbers shall be a minimum of 24 in. (0.6 m) in height and affixed with their base toward the front of the vehicle. Numbering, lettering, and striping shall be in sharp contrast to the vehicle color.

Chapter 2 Major Fire-Fighting Vehicles

2-1 General.

2-1.1

The category of major vehicles shall encompass a range of water capacity commencing at 1000 gal (3785 L) and extending to over 6000 gal (22 710 L). Because the same performance cannot be expected of all vehicles within this range, vehicles shall be classified into water capacity ranges within which a similar level of performance is practical.

2-1.2

Table 2-1.2 provides vehicles rated in gallons that shall be used to establish the class of vehicle.

Table 2-1.2 Vehicle Water Capacities

Minimum Rated Water Capacity

Class	(gal)	(L)
1	1000	3785
2	1500	5677.5
3	2500	9462.5
4	3000	11,355
5	4000	15,140
6	5000	18,925
7	6000	22,710

2-2 Weights and Dimensions.

2-2.1 Weights.

2-2.1.1 The actual gross vehicle weight of a fully staffed, loaded, and equipped vehicle ready for service shall not exceed the manufacturer's gross vehicle weight rating.

2-2.1.2* The weight shall be distributed as equally as practical over the axles and tires of the fully loaded vehicle. The difference in weight between tires on any axle shall not exceed 5 percent of the average tire weight for that axle. The difference in weight between any two axles shall not exceed 10 percent of the weight of the heaviest axle if the heavy axle is a rear axle. If the heavy axle is a front axle, the weight difference between that axle and any other axle shall not exceed 5 percent of the heavy axle weight. Under no circumstances shall the axle and tire manufacturers' ratings be exceeded.

2-2.1.3 The center of gravity of the vehicle shall be kept as low as possible under all conditions of loading. Vehicles in Classes 1, 2, 3, and 4 through 7 shall be able to stand on sideways slopes of 30 degrees, 28 degrees, 26.5 degrees, and 24 degrees (58 percent, 53 percent, 50 percent, and 45 percent, respectively).

2-2.1.4 The vehicle also shall be driven on a steering pad around a circle with a radius of 100 ft (30.5 m). The steering wheel rotation shall increase with acceleration of speed to ensure the vehicle does not exhibit oversteer characteristics. A speed in excess of 22 mph (35.4 km/h) shall be obtained with vehicles in Classes 1 and 2, and a speed in excess of 18.5 mph (29.8 km/h) shall be obtained with Classes 3 through 7 vehicles.

2-2.2 Dimensions.

2-2.2.1 The vehicle clearance shall allow mobility in soft soils and rough terrain with the vehicle tires inflated to highway inflation pressures. The minimum dimensions shall be as follows:

(a) Angle of approach — 30 degrees;

(b) Angle of departure — 30 degrees;

(c) Interaxle clearance angle — 12 degrees;

(d) Underaxle clearance — 13-in. (33.0-cm) underaxle differential housing bowl;

(e) Underbody clearance — 18 in. (45.7 cm).

2-2.2.2* The overall height, length, and width of the vehicle shall be held to a minimum consistent with the best operational performance of the vehicle and the design concepts needed to achieve this performance and to provide optimum maneuverability and facilitate movement on public highways.

2-2.2.3 The vehicle shall be constructed so that a seated driver, having an eye reference point of $31^3/_4$ in. (806.5 mm) above the seat cushion and 12 in. (30.5 cm) forward from the seat back, shall be able to see the ground 20 ft (6.1 m) ahead of the vehicle and shall have a field of vision of at least 5 degrees above the horizontal plane. The field of vision in the horizontal plane shall be at least 90 degrees on each side from the straight ahead position.

2-2.2.4 Adjustable rear view mirrors with a glass area of not less than 60 in.^{2} (387.1 cm^2) shall be provided on each side of the vehicle. Each side shall be provided with a minimum 7-in.^{2} (45.2-cm^2) wide-angle (convex) mirror.

Exception: In lieu of mirrors, audiovisual devices that meet or exceed the field of vision provided by the wide-angle mirrors shall be permitted.

2-3 Engine.

2-3.1 Performance Requirements.

2-3.1.1 The vehicle engines shall have sufficient horsepower, torque, and speed characteristics to meet and maintain all vehicular performance characteristics specified in this standard. The engine manufacturer shall certify that the installed engine is approved for this application.

2-3.1.2* The fully loaded vehicle shall be able to accelerate consistently from 0 mph to 50 mph (0 km/h to 80.5 km/h) on dry, level concrete pavement at the operational airport within the times specified in Table 2-3.1.2. The maximum speed shall not be less than 65 mph (104.6 km/h). If any vehicle accelerates from 0 mph to 50 mph (0 km/h to 80.5 km/h) in less than 20 seconds, it shall meet the tilt-table parameters of 35 degrees side slope as a minimum for all classes.

The acceleration times provided in Table 2-3.1.2 shall be achieved with the engine and transmission at their normal operating temperatures at any ambient temperature from 0°F to 110°F (-17.8°C to 43.3°C) and at elevations up to 2000 ft (609.6 m) above sea level unless a higher elevation is specified.

For airports above 2000 ft (609.6 m), the elevation at which the vehicle shall operate in order to ensure the necessary performance shall be specified.

Table 2-3.1.2 Vehicle Acceleration Requirements

Class	Minimum Water Capacity		Maximum Acceleration Time 0 mph to 50 mph (0 km/h to 80 km/h)
	U.S. (gal)	(L)	(sec)
1	1000	4000	23

2	1500	6000	26
3	2500	9000	35
4	3000	11,000	40
5	4000	15,140	45
6	5000	18,925	50
7	6000	22,710	50

2-3.1.3 The vehicle also shall be capable of ascending, stopping, starting, and continuing ascent on a 40-percent grade on dry pavement at a speed up to at least 1 mph (1.6 km/h) with extinguishing agents being discharged from the primary turret nozzle(s).

2-3.2 Engine Cooling Systems.

2-3.2.1 Liquid-Cooled Engines. An engine coolant preheating device shall be provided as an aid to rapid starting and high initial engine performance. This device shall be fitted with a thermostat.

2-3.2.1.1 The cooling system shall be designed so that the stabilized engine coolant temperature remains within the engine manufacturer's prescribed limits under all operational conditions and at all ambient temperatures encountered at the operational airport. The cooling system shall be provided with an automatic thermostat for rapid engine warming.

2-3.2.1.2 Where specified, radiator shutters, where furnished for cold climates, shall be of the automatic type and shall be designed to open automatically upon failure.

2-3.2.2 Air-Cooled Engines. Air-cooled engines shall be designed so that the stabilized cylinder head and oil temperatures remain within the engine manufacturer's prescribed limits under all operational conditions and at all ambient temperatures encountered at the operational airport.

2-3.3 Fuel System.

2-3.3.1 A complete fuel system installed with the engine manufacturer's approval shall include a fuel pump, fuel filtration, and flexible fuel lines, where necessary, that shall be protected from damage, exhaust heat, and exposure to ground fires.

2-3.3.2 Accessible filtration shall be provided for each fuel supply line, and a drain shall be provided at the bottom of the fuel tank.

2-3.3.3 Fuel tanks shall not be installed in a manner that allows gravity feed.

2-3.3.4 The fuel tank shall have sufficient capacity to provide for a minimum of 30 mi (48.3 km) of highway travel at 55 mph (88.5 km/h) plus 2 hours of pumping at the full rated discharge. Additional fuel capacity shall be provided for a minimum of 4 hours of operation of each accessory item (such as a generator or fuel-fired heaters) that uses the common fuel tank as a source.

2-3.4 Exhaust System.

2-3.4.1 The exhaust system shall be of a size that avoids undue back pressure and shall be located and constructed in such a manner that entrance of exhaust gases into the cab is minimized under all conditions of operation. The exhaust system shall be of high-grade, rust-resistant materials. The exhaust system shall include a muffler to reduce engine noise.

2-3.4.2 The exhaust system shall be protected from damage that could result from traversing rough terrain. The tail pipe shall be designed to discharge upward or to the rear and shall not be directed toward the ground.

2-4 Vehicle Electrical System.

2-4.1

The vehicle shall be provided with one of the following electrical systems:

(a) A 12-volt electrical and starting system;

(b) A 24-volt electrical and starting system;

(c) A 12-volt electrical/24-volt starting system.

2-4.2

The electrical system shall have a negative ground including a transistorized alternator and a fully transistorized voltage regulator. The alternator shall be rated at 100 percent of the anticipated load at 50 percent of the engine-governed speed and, if belt driven, it shall be driven by dual belts.

2-4.2.1 For 12-volt electrical and starting systems and for 12-volt electrical/24-volt starting systems, the curb idle minimum charging rate of the alternator shall be 50 amperes.

2-4.2.2 For 24-volt electrical and starting systems, the curb idle minimum charging rate of the alternator shall be 30 amperes.

2-4.3

Batteries shall be mounted securely and adequately protected against physical injury and vibration, water spray, and engine and exhaust heat. Where an enclosed battery compartment is provided, it shall be ventilated adequately, and the batteries shall be readily accessible for examination, test, and maintenance.

2-4.3.1 For 12-volt starting systems, the batteries shall be connected so that their capacity meets the cold-cranking performance amperes at 0°F (-17.8°C) to comply with the engine manufacturer's recommendations. In addition to the cold-cranking performance ampere requirements, a minimum reserve capacity of 600 minutes at 80°F (26.7°C) shall be provided.

2-4.3.2 For 24-volt starting systems, the batteries shall be connected so that their capacity meets the cold-cranking performance amperes at 0°F (-17.8°C) to comply with the engine manufacturer's recommendations.

2-4.4 Battery Capacity.

2-4.4.1 Battery capacity and wiring circuits, including the starter switch and circuit and the starter to battery connections, shall meet or exceed the manufacturer's recommendations. A master power disconnect system shall isolate power from all of the electrical system except the primary power circuits to the alternator and starter. Exceptions shall apply only to systems that are required to operate when the vehicle is not attended. The control device shall be accessible from the driver's seated position.

2-4.4.2 For 12-volt electrical/24-volt starting systems, the batteries shall be connected in a series parallel through a solid-state series parallel circuit to accomplish 24-volt starting. The batteries shall be connected so that their capacity meets the cold-cranking performance amperes at 0°F (-17.8°C) to comply with the engine manufacturer's recommendations. In addition to the cold-cranking ampere requirements, a minimum reserve capacity of 600 minutes at 80°F (26.7°C) shall be provided.

2-4.5 Battery Chargers.

2-4.5.1 A built-in battery charger shall be provided on the vehicle to maintain full charge on all batteries. A grounded AC receptacle shall be provided to allow a pull-away connection from the local electric power supply to the battery charger.

2-4.5.2 Where specified, an on-board battery charger/conditioner shall be provided on the vehicle and shall have a minimum output rating of one-half percent of the cold-cranking ampere rating at 32°F (0°C) of the engine-starting battery system. The battery charger shall be supplied from an external power source of 115 volts or 220 volts AC. This battery charger/conditioner shall be the type that can be connected to the batteries at all times and yet maintain a charge to the batteries without causing any damage. The unit shall reduce its charging output level to a point where a small amount of charge is allowed to the batteries continuously or it shall shut off completely. The charger/conditioner shall have protection built into it to protect it from damage during high current demands such as those caused by starting the engine. The unit shall be provided with a grounded AC receptacle to allow a pull-away connection from the local electrical power supply to the battery charger/conditioner.

2-4.6

The electrical system and its components shall be weatherproof, insulated, and protected from chafing, damage from road debris, and exposure to ground fires. All wiring shall be coded to correspond with the wiring diagram provided with the vehicle. Circuit protection shall be provided to protect the vehicle in the event of electrical overload.

2-4.7

Radio suppression of the electrical system shall be in accordance with SAE J551, *Standard on Performance Levels and Methods of Measurement of Electromagnetic Radiation from Vehicles and Devices (30-1000 MHz)*, or an equivalent radio suppression standard.

2-5 Vehicle Drive.

Transmission of power from the engine to the wheels of the vehicle shall be through a torque converter and an automatic or a semiautomatic gearbox. The entire drive train shall be designed and rated by the component manufacturer as having sufficient capacity to slip the wheels of the static-loaded vehicle on a surface having a coefficient of friction of 0.8. A range of gears providing the specified top speed and a grade ability of 50 percent shall be provided with sufficient intermediate gears to achieve the specified acceleration. The transmission shall be matched to the engine properly and shall be approved for the application by the transmission manufacturer.

2-5.1

A transmission cooling system shall be provided and designed so that the stabilized transmission oil temperature remains within the transmission manufacturer's prescribed limits under all operational conditions and at all ambient temperatures encountered at the operational airport.

2-5.2

A positive drive shall be provided to each wheel by means of a fully locked driveline in order to maximize traction on low-friction surfaces. Positive drive shall be permitted to be achieved either by the use of automatic locking and torque proportioning differentials or shall be permitted to be selected manually by the seated driver by use of a single control while the vehicle is in motion.

2-5.3

All-wheel drive on these vehicles shall incorporate a drive to the front and rear axles that is engaged at all times during the intended airport service. An interaxle differential shall be installed with automatic means or driver-selected means of differential locking.

2-5.4

All traction-increasing devices shall be operated by a single control for driving simplicity.

2-5.5

Front and rear axles shall have adequate capacity to carry the maximum imposed load under all intended operating conditions. The variations in axle tread shall not exceed 20 percent of the tire sectional width at rated load.

2-6 Suspension.

The suspension system shall be designed to allow the loaded vehicle to perform as follows:

(a) Travel at the specified speeds over improved surface;

(b) Travel at moderate speeds over unimproved surface;

(c) Provide diagonally opposite wheel motion 14 in. (355.6 mm) above ground obstacles without raising the remaining wheels from the ground;

(d) Prevent damage to the vehicle caused by wheel movement; and

(e) Provide a good environment for the crew when traveling over all surfaces.

2-7 Rims, Tires, and Wheels.

2-7.1

Vehicles shall be required to have off-highway mobility while meeting the specified paved surface performance.

2-7.2

Tires shall be selected to maximize the acceleration, speed, braking, and maneuvering capabilities of the vehicle on paved surfaces without sacrificing performance on all reasonable terrains found within the airport boundary.

2-7.3*

The purchaser shall provide a tire description that reflects the off-road performance requirements necessitated by the soil conditions encountered at the operational airport. Soil conditions that vary from an extremely fine grain soil or clay to an extremely coarse grain soil, sand, or gravel in a dry, saturated, or frozen condition shall be considered.

To optimize floatation under soft ground conditions, tires of larger diameter or width, or both, than is needed for bearing weight only shall be specified. Similarly, the lowest tire pressure compatible with the high speed performance requirements also shall be specified.

2-7.4

Vehicle and tire manufacturers shall be consulted for the tread design most suitable for the specific soil composition at individual airports.

2-7.5

All wheels on the vehicle shall be of the single-wheel type with all rims, tires, and wheels of an identical size and the same tire tread design.

2-7.6

Rims, tires, wheels, and inflation pressures shall be approved by their respective manufacturers as having sufficient capacity to meet the specified performance and shall be certified for not less than 5 mi (8 km) of continuous operation at 65 mph (104.6 km/h) at normal operational pressure.

2-8* Towing Connections.

At least two large tow eyes or tow hooks (one at the front and one at the rear), capable of towing the vehicle on level ground without damage, shall be mounted on the truck and attached directly to the frame structure or where recommended by the vehicle manufacturer.

2-9 Brakes.

2-9.1*

The braking system shall feature service, emergency, and parking brake systems. Service brakes shall be of the power-actuation air, hydraulic, or air-over-hydraulic type. Expanding shoe and drum brakes or caliper disc brakes shall be furnished. A brake chamber shall be provided for each wheel and shall be mounted so that no part of the brake chamber projects below the axle bowl.

2-9.2*

Service brakes shall be of the all-wheel type with split circuits so that failure of one circuit shall not cause total service brake failure.

2-9.2.1 The service brakes shall be capable of holding the fully loaded vehicle on a 50 percent grade.

2-9.2.2 For Classes 1, 2, and 3 vehicles, the service brakes shall stop the vehicle within 35 ft (10.7 m) at 20 mph (32.2 km/h), and within 131 ft (39.9 m) at 40 mph (64.4 km/h).

2-9.2.3 For Classes 4 through 7 vehicles, the service brakes shall stop the vehicle within 40 ft (12.2 m) at 20 mph (32.2 km/h) and within 160 ft (48.8 m) at 40 mph (64.4 km/h).

2-9.2.4 Stopping distances shall be accomplished on a dry, hard, approximately level roadway that is free from loose material and that has a roadway width equal to the vehicle width plus 4 ft (1.2 m) without any part of the vehicle leaving the roadway.

2-9.2.5 For each vehicle class, the service brakes shall provide one power-assisted stop while the vehicle engine is inoperative for the stopping distances specified in 2-9.2.2 through 2-9.2.4.

2-9.3

An emergency brake system shall be provided that is applied and released by the driver from the cab and is capable of modulation by means of the service brake control. When a single failure in the service brake system of a part designed to contain compressed air or brake fluid occurs, other than failure of a common valve, manifold, brake fluid housing, or brake chamber housing, the vehicle shall stop within no more than 288 ft (87.8 m) at 40 mph (64.4 km/h) without any part of the vehicle leaving a dry, hard, approximately level roadway that has a width equal to the vehicle width plus 4 ft (1.2 m).

2-9.4

The parking brake shall be capable of holding the fully loaded vehicle on a 20-percent grade without air or hydraulic assistance.

2-9.5 Brakes — Air System.

2-9.5.1 Where the vehicle is supplied with air brakes, the air compressor shall meet the following criteria:

(a) The compressor shall be engine driven;

(b) The compressor shall have sufficient capacity to increase air pressure in the supply and service reservoirs from 85 psi to 100 psi (586.1 kPa to 689.5 kPa) when the engine is operating at the vehicle manufacturer's maximum recommended revolutions per minute (rpm) in a maximum of 25 seconds;

(c) The compressor shall have the capacity for quick buildup of tank pressure from 0 psi (0 kPa) to the pressure to release spring brakes, and this buildup in pressure shall be accomplished within 15 seconds; and

(d) The compressor shall incorporate an automatic air-drying system immediately downstream from the compressor to prevent condensation buildup in all pneumatic lines.

2-9.5.2 Service reservoirs shall be provided. The calculated reservoir capacity shall include reservoirs, supply lines, and air dryer volumes. The total of the service reservoir volume shall be at least twelve times the total combined brake chamber volume at full stroke. If the reservoir volume is greater than the minimum required, a proportionately longer buildup time shall be allowed using the following formula:

$$\frac{\text{Actual reservoir capacity} \times 25}{\text{Required reservoir capacity}}$$

2-9.5.3 Reservoirs shall be equipped with drain valves and safety valves.

2-9.5.4 Provision shall be made for charging of air tanks with either a pull-away electrical connection used to power a vehicle-mounted auxiliary compressor or a pull-away air connection for charging of air tanks from an external air source.

2-9.5.5 Visual and audible low air pressure warning devices shall be provided. The low pressure warning device shall be visual and audible from the inside of the vehicle and shall be audible from the outside of the vehicle.

2-10 Steering.

2-10.1

The chassis shall be equipped with power-assisted steering with direct mechanical linkage from the steering wheel to the steered axle(s) to allow manual control in the event of power-assist failure.

2-10.2

The power steering system shall have sufficient capacity so that no more than 15 lbf (66.7 N) pull is needed on the steering wheel rim in order to turn the steering linkage from stop to stop with the fully loaded vehicle stationary on a dry, level, paved surface with the engine at idle.

2-10.3

The wall-to-wall turning diameter of the fully loaded vehicle shall be less than three times the vehicle length.

2-11 Cab.

2-11.1

The cab shall be fully enclosed (i.e., floor, roof, and four sides) and mounted on the forward part of the vehicle. Seating for the crew shall be restricted to the cab. The maximum number of crew seat positions provided in the cab shall be designated by the manufacturer and so labeled in the cab. As a minimum, two designated seat positions shall be provided, one for the driver and one for an additional crew member. Seat belts approved by the authority having jurisdiction shall be provided for each of the designated seating positions. Space shall be provided for all instrument controls and equipment specified without hindering the crew. Doors that open to as wide a position as possible shall be provided on each side of the cab with the necessary steps and handrails to allow rapid and safe entrance and exit from the cab. The cab design shall take into consideration the provision of ample space for the crew to enter and exit the cab and carry out normal operations while wearing full protective equipment.

2-11.2

The cab shall meet the visibility requirements of 2-2.2.3. Interior cab reflections from exterior and interior lighting shall be minimized. The windshield shall be shatterproof safety glass, and all other windows shall be constructed of approved safety glass. The cab shall be provided with wide gutters to prevent foam and water from dripping on the windshield and side windows. Where equipped with a roof turret having manual controls above the cab roof, the cab shall be designed with a quick-access passage to the roof turret(s).

2-11.3

The cab shall be weatherproof and shall be fully insulated thermally and acoustically with a fire-resistant material. The cab interior noise level at any seated position shall not exceed 85 dBA while traveling at 50 mph (80.5 km/h) on a level, hard surface without warning devices operating. With warning devices operating, the maximum limit shall be 90 dBA. The cab shall be permitted to be of the unitized rigid body and frame structure type, or it shall be permitted to be a separate unit flexibly mounted on the main vehicle frame. The cab shall be constructed from materials of adequate strength to ensure a high degree of safety for the crew under all operating conditions, including excess heat exposure and vehicle roll-over accidents.

2-11.4 Instruments, Warning Lights, and Controls.

2-11.4.1 The minimum number of instruments, warning lights, and controls consistent with the safe and efficient operation of the vehicle, chassis, and fire-fighting system shall be provided. All chassis instruments and warning lights shall be grouped together on a panel in front of the driver. All fire-fighting system instruments, warning lights, and controls shall be grouped together by function to provide ready accessibility and high visibility for the driver as well as crew members.

2-11.4.2 All instruments and controls shall be illuminated, and backlighting shall be used where practical.

2-11.4.3 Groupings of both the chassis and fire-fighting system instruments, warning lights, and controls shall be easily removable as a unit or shall be on a panel hinged for back access by the use of quick-disconnect fittings for all electrical, air, and hydraulic circuits.

2-11.4.4 The following instruments or warning lights, or both, shall be provided as a minimum:

(a) Speedometer/odometer;

(b) Engine(s) tachometer;

(c) Fuel level;

(d) Air pressure;

(e) Engine(s) temperature;

(f) Engine(s) oil pressure;

(g) Voltmeter(s);

(h) Transmission(s) oil temperature;

(i) Pump(s) pressure;

(j) Water tank level;

(k) Foam tank level;

(l) Low air pressure warning;

(m) Headlight beam indicator;

(n) Engine hour meter.

2-11.4.5 The cab shall have all the necessary controls within easy reach of the driver for the full operation of the vehicle and the pumping system. The following cab controls shall be provided:

(a) Accelerator pedal;

(b) Brake pedal;

(c) Parking brake control;

(d) Steering wheel, with directional signal control and horn;

(e) Transmission range selector;

(f) Pump control or selector;

(g) Foam control;

(h) Siren switch(es);

(i) Bumper turret controls or ground sweep valve control;

(j) Where specified, undertruck valve control;

(k) Remote turret controls, where remote turret is provided;

(l) Light switches;

(m) Windshield wipers with delayed and multispeed capability and washer controls;

(n) Heater/defroster controls;

(o) Master electrical switch;

(p) Means of starting and stopping engine;

(q) Auxiliary agent pressurization control, where specified;

(r) Windshield deluge system switch, where specified.

2-11.4.6 Where specified, a windshield deluge system shall be included to cool the windshield and to provide operator visibility during fire-fighting operations. It shall be designed to flood the windshield with clear water when activated. Clear water shall be discharged under sufficient pressure and in a pattern that ensures the driver/operator's field of vision can be kept clear of foam solution where used in conjunction with the windshield wiper. The windshield wipers shall be energized automatically whenever the deluge system is operated.

2-11.5 Equipment.

All interior crew and driving compartment door handles shall be designed and installed to protect against accidental or inadvertent opening.

2-11.5.1 The following equipment shall be provided in or on the cab, as applicable:

(a) Heater/defroster;

(b) Driver's suspension seat with vertical, fore, and aft adjustment, with seat belt;

Exception: The use of a nonsuspension driver's seat shall be permitted where recommended by the manufacturer.

(c) Crew seats with individual retractable seat belts;

(d) Windshield washers appropriate for removing foam;

(e) Windshield wipers appropriate for removing foam;

(f) Siren;

(g) Horn;

(h) Sun visors, interior transparent;

(i) Outside rear view mirrors, as specified in 2-2.2.4;

(j) Interior lighting;

(k) Provisions for mounting SCBA of the type specified by the purchaser at each crew seat position.

2-11.5.2 Where tools, equipment, or SCBA are carried within enclosed seating areas of fire department vehicles, such items shall be secured by either a positive mechanical means of holding the item in its stored position or in a compartment with a positive latching door. The means for holding the item in place or in the compartment shall be designed to minimize injury to persons in the enclosed area of the vehicle caused by loose equipment during travel and, in the event of an accident, a rapid deceleration or a rapid acceleration.

2-11.6

Signs that state "Occupants must be seated and wearing a seat belt when apparatus is in motion" shall be provided. Such signs shall be visible from each seated position. An accident prevention sign shall be located at the rear step area of the vehicle, if it exists. It shall warn personnel that standing on the step while the vehicle is in motion is prohibited.

2-12 Body.

2-12.1

The body shall be constructed of materials that are of the lightest weight consistent with the strength necessary for off-pavement operation over rough terrain and where exposed to excess heat. The body shall be permitted to be of the unitized-with-chassis-rigid-structure type or it shall be permitted to be flexibly mounted on the vehicle chassis. It also shall include front and rear fenders or wheel wells. Body panels shall be removable where necessary to provide access to the interior of the vehicle.

2-12.2

Access doors shall be provided for those areas of the interior of the vehicle that are inspected frequently. In particular, access doors of sufficient size and number shall be provided for access to the following:

(a) Engine;

(b) Pump;

(c) Foam proportioning system;

(d) Battery storage;

(e) Fluid reservoirs.

Other areas that need to be accessible for inspection or maintenance shall be open or shall have removable panels.

2-12.3

Suitable, lighted compartments shall be provided for convenient storage of equipment and tools to be carried on the vehicle. Compartments shall be weathertight and self-draining.

2-12.4

A working deck shall be provided and shall be reinforced adequately to allow the crew to perform its duties in the roof turret area, cab hatch area, water tank top fill area, foam-liquid top fill area, and in other areas where access to auxiliary or installed equipment is necessary.

2-12.5

Handrails or bulwarks shall be provided where necessary for the safety and convenience of the crew. Rails and stanchions shall be braced strongly and constructed of a material that is durable and resists corrosion. Handrails shall be constructed of, or covered with, a slip-resistant material.

2-12.6

Steps or ladders shall be provided for access to the top fill area. The lowermost step(s) shall be permitted to extend below the angle of approach or departure or ground clearance limits if it is designed to swing clear. All other steps shall be rigidly constructed. All steps shall have a nonskid surface. The lowermost step(s) shall be no more than 22 in. (558.8 mm) above level ground when the vehicle is fully loaded. Adequate lighting shall be provided to illuminate steps and walkways.

2-12.7

A heavy-duty front bumper shall be mounted on the vehicle and secured to the frame structure.

2-12.8

Vehicle numbering, lettering, and minimum 8-in. (20.3-cm) wide reflective striping shall be provided in accordance with ASTM D4956, *Standard Specification for Retroreflective Sheeting for Traffic Control*. Striping shall be placed on at least 60 percent of the perimeter length of each side, width, and rear. At least 40 percent of the perimeter width of the front of the vehicle shall have the reflective stripe.

Exception: A graphic design meeting the reflectivity requirements of this paragraph shall be permitted to replace all or part of the required striping, provided the design or combination thereof covers a minimum of the same perimeter length required above.

2-12.9

Attachments shall be provided for all tools, equipment, and other items that the purchaser specifies to be furnished on the vehicle. Equipment holders shall be attached firmly and designed so that equipment remains in place under all operating conditions, but the equipment shall be quickly removable for use.

2-13 Fire-Fighting Systems and Agents.

2-13.1 General.

2-13.1.1 For aircraft rescue and fire-fighting purposes, the primary and auxiliary extinguishing agents used shall be tested in accordance with NFPA 403, *Standard for Aircraft Rescue and Fire Fighting Services at Airports*.

2-13.1.2 Vehicles designed to discharge auxiliary agents shall require the use of auxiliary agents that are compatible with the primary agent.

2-13.1.3 All components of the agent systems, including such items as the tanks, piping, fill troughs, and screens, shall be made of materials resistant to corrosion by the primary agent, primary agent/water solution, water, and, where specified, the auxiliary agent.

2-14 Agent Pump(s) and Pump Drive.

2-14.1 Agent Pump(s).

2-14.1.1 The water pump(s) shall be constructed of corrosion-resistant metals and shall be of the single-stage or multiple-stage centrifugal type and shall be designed for dependable emergency service. Pumps shall be designed carefully and built in accordance with good modern practice. Pumps shall be gravity primed from the vehicle tank. The pump and piping system shall be designed to eliminate the entrapment of air.

2-14.1.2 All proportioning system components shall be made of materials resistant to corrosion by all primary agents.

2-14.1.3 Where discharging foam solution, the pumping system shall be capable of discharging at a rate equal to or exceeding the total requirements of the roof or extendable turret(s), bumper turret or ground sweep nozzles, preconnected hand line nozzles, and undertruck nozzles, where specified, discharging simultaneously at designed pressures.

2-14.2 Pump Drive.

2-14.2.1 The pump(s) drive shall allow operation of the pump(s) and simultaneous operation of the vehicle. The pump(s) shall not be affected by changes in transmission ratios or the actuation of clutches in the vehicle drive. The design of the drive system and controls shall prevent damage to the drive or shall minimize lurching of the vehicle when the vehicle drive is engaged during pumping operations. The pump(s) drive system shall be capable of absorbing the maximum torque delivered by the engine to the pump(s) and withstanding the engagement of the pump(s) at all engine and vehicle speeds and under all operating conditions. The operation of the pump(s) shall not, under any conditions, cause the engine to stall or cause more than a slight and momentary reduction in engine speed and consequent drop in pump pressure.

2-14.2.2 While pumping at rated capacity, the drive shall allow controlled vehicle operation at speeds from 1 mph to 5 mph (1.6 km/h to 8 km/h). The pump(s) drive shall have sufficient power capacity to provide the pump(s) discharge requirements of 2-14.1.3 while the vehicle is being propelled under all operating conditions where a fire-fighting capability is needed.

2-14.2.3 If an independent engine is used to drive the pump(s), it shall have the same fuel and electrical system as the chassis engine and shall be equipped with an air cleaner, a replaceable element oil filter, a full pressure lubricating system, and an overspeed governing device to prevent engine damage. The engine also shall be provided with a cooling system that meets the requirements of 2-3.2.1 or 2-3.2.2.

2-14.3 Suction Connections.

2-14.3.1 The suction system shall be designed for efficient flow at the pumping rates required by 2-14.1.3. The pump suction line(s) shall be of large diameter and of the shortest length consistent with the most suitable pump location. There shall be a drain at the lowest point with a valve for draining all of the liquid from the pumping system where desired. Suction lines and valves shall be constructed of corrosion-resistant materials.

2-14.3.2 Where two pumps are used, they shall be arranged in parallel with manifolding so that either or both can supply any discharge outlet at the required operating pressure. During single pump operation, the total capacity shall be permitted to be reduced.

2-14.4 Discharge Connections.

All discharge outlets shall have National (American) Standard fire hose coupling thread. Adapter couplings, securely attached, shall be provided on each outlet if local couplings are not National (American) Standard as specified in NFPA 1963, *Standard for Fire Hose Connections*. No outlet or outlet with adapters shall add width to the vehicle.

2-14.5 Piping, Couplings, and Valves.

2-14.5.1 All piping, couplings, and valves shall be sized for necessary flow with minimum restriction and pressure loss. Material for all piping, couplings, and valves shall be selected to avoid corrosive or galvanic action.

2-14.5.2 Piping shall be mounted securely and provided with flexible couplings to minimize stress. Union or rubber-gasketed fittings shall be provided where necessary to facilitate removal of piping.

2-14.5.3 All valves shall be of the quarter-turn type and shall be selected for ease of operation and freedom from leakage.

2-14.5.4 All water system piping shall be tested on the suction side of the pump to detect possible leakage. All water and foam solution discharge piping, together with the agent pump(s), shall be tested at 50 percent above the system operating pressure.

2-14.6 Overheat Protection.

A system line shall be provided from the water pump discharge and, if applicable, from the foam pump discharge to prevent overheating of the pumps while engaged and operating at zero (0) discharge. The line shall be automatic.

2-14.7 Pressure Relief Valves.

A pressure relief valve shall be fitted both to protect and ensure optimum performance of the system.

2-14.8 Drains.

A drainage system with collector tubing from the low points on the pump(s) and piping shall be provided. The drain shall be provided with a quarter-turn valve.

2-15 Water Tank.

2-15.1 Capacity.

2-15.1.1 A water tank shall have a usable capacity as specified in 2-1.2.

2-15.1.2 The rated capacity of the tank shall be equal to the usable capacity that can be pumped from the tank while the vehicle is parked on level ground. The tank outlets shall be arranged to allow the use of at least 75 percent of the rated capacity with the vehicle positioned as follows:

(a) On a 20-percent side slope;

(b) On a 30-percent ascending grade;

(c) On a 30-percent descending grade.

2-15.2 Construction.

2-15.2.1 The tank shall be constructed to resist all forms of deterioration that could be caused by the water and foam concentrate while affording the structural integrity necessary for off-road operation. The tank shall have longitudinal and transverse baffles. The construction and connections shall be made to prevent the possibility of galvanic corrosion of dissimilar metals.

2-15.2.2 The tank shall be equipped with easily removable manhole covers over the tank discharge. Where specified, the tank shall be designed to allow access within each baffled compartment of the tank for internal and external inspection and service. The tank shall have a drain valve(s).

2-15.2.3 Provisions shall be made for necessary overflow and venting. Venting shall be sized to allow agent discharge at the maximum design flow rate without danger of tank collapse and shall be sized to allow rapid and complete filling without exceeding the internal pressure design limit of the tank. Additionally, overflows shall be designed to prevent loss of water from the tank during normal maneuvering and to direct the discharge of overflow water directly to the ground.

2-15.2.4 The water tank shall be mounted in a manner that limits the transfer of the torsional strains from the chassis frame to the tank during off-pavement driving. The tank shall be separate and distinct from the crew compartment, engine compartment, and chassis and shall be easily removable as a unit. Water tanks used as an integral part of unitized rigid body construction shall be permitted.

2-15.2.5 The water tank shall be equipped with at least one top fill opening of not less than 8 in. (20.3 cm) internal diameter. The top fill shall be equipped with an easily removable strainer of $^{1}/_{4}$-in. (6.4-mm) mesh construction. The top fill opening shall be equipped with a cap designed to prevent spillage.

2-15.3 Tank Fill Connection(s).

2-15.3.1 A tank fill connection(s) shall be provided in a position where it can be reached easily from the ground.

2-15.3.2 All connections shall have National (American) Standard fire hose coupling threads. Securely attached adapters shall be provided on each connection if local couplings are not National (American) Standard. Connections and adapter threads shall be as specified in NFPA 1963, *Standard for Fire Hose Connections*. Connections and connections with adapters attached shall not protrude beyond the normal body metalwork of the vehicle.

2-15.3.3 The connection(s) shall be provided with strainers of $^{1}/_{4}$-in. (6.4-mm) mesh and shall have check valves or shall be constructed so that water is not lost from the tank when connection or disconnection is made.

2-15.3.4 The tank fill connection(s) shall be sized to allow filling of the water tank in 2 minutes at a pressure of 80 psi (551.6 kPa) at the tank intake connection.

2-16 Foam System.

2-16.1 Foam-Liquid Concentrate Tank(s).

2-16.1.1 The purchaser shall specify the percent concentrate foam system to be provided. The foam-liquid concentrate tank(s) shall have a working capacity sufficient for two tanks of water at the maximum tolerance specified in NFPA 412, *Standard for Evaluating Aircraft Rescue and Fire Fighting Foam Equipment*.

2-16.1.2 Foam-liquid concentrate tanks shall be permitted to be of either the rigid or flexible type. Where specified, the tank(s) shall be designed for compatibility with the foam concentrate being used and shall resist all forms of deterioration that could be caused by the foam concentrate or water.

2-16.1.3 Tanks shall be designed to allow access within each baffled compartment of the tank for internal and external inspection and service. A large capacity drain connection shall be installed flush with the bottom of the sump.

2-16.1.4 The tank outlets shall be located above the bottom of the sump and shall provide continuous foam-liquid concentrate to the foam proportioning system, with that system operating as specified in 2-16.4 and with the vehicle discharging two tank loads of usable water as specified in 2-15.1.

2-16.1.5 If separate from the water tank, the foam-liquid tank shall be mounted in a manner that limits the transfer of the torsional strains from the chassis frame to the tank during off-pavement driving. The tank shall be separate and distinct from the crew compartment, engine compartment, and chassis and shall be easily removable as a unit. Foam liquid tanks used as an integral part of unitized rigid body construction shall be permitted.

A flexible tank shall be structurally supported to resist tearing. The structural support shall not be dependent on the fluid level in either the water or foam tanks.

2-16.1.6 A top fill trough shall be provided and shall be equipped with a stainless steel No. 10 mesh screen and container openers to allow emptying 5-gal (18.9-L) foam-liquid concentrate containers into the storage tank(s) at a rapid rate regardless of water tank level. The trough shall be connected to the foam-liquid storage tank(s) with a fill line designed to introduce foam-liquid concentrate near the bottom of the tank(s) to minimize foaming within the storage tank.

2-16.1.7 The tank fill connection(s) shall be provided in a position where it can be reached easily from the ground to allow the pumping of foam-liquid concentrate into the storage tank(s). The connection(s) shall be provided with strainers of $^1/_4$-in. (6.4-mm) mesh and shall have check valves or shall be constructed so that foam is not lost from the tank when connection or disconnection is made.

Where flexible tanks are used, the supply system shall be designed so that the flexible tanks are not subject to excess pressure. The supply system shall be capable of delivering foam-liquid at a rate at least equal to or greater than the maximum discharge rate of the foam system.

2-16.1.8 The tank(s) shall be vented adequately to allow rapid and complete filling without the buildup of excessive pressure and to allow emptying of the tank at the maximum design flow rate without danger of collapse. The vent outlets shall be directed to the ground to prevent spillage of foam-liquid concentrate on vehicle components.

2-16.2 Foam-Liquid Concentrate Pump.

2-16.2.1 The foam-liquid concentrate system shall be arranged so that the entire piping system, including the foam-liquid concentrate pump or pumps, can be flushed readily with clear water.

2-16.2.2 The foam-liquid concentrate pump or pumps shall be capable of delivering the necessary quantity of foam-liquid at a pressure in excess of the water pump operating pressure, regardless of the water flow rate or variations in engine speed.

2-16.3 Foam-Liquid Concentrate Piping.

2-16.3.1* The foam-liquid concentrate piping shall be of material resistant to corrosion by foam-liquid concentrates addressed in this standard. Care shall be taken that combinations of dissimilar metals that produce galvanic corrosion are not selected or that such dissimilar metals are electrically insulated. Where plastic piping is used, it shall be fabricated from unplasticized resins, unless it has been demonstrated that the stipulated plasticizer does not adversely affect the performance characteristics of the foam-liquid concentrates addressed in this standard. The plastic pipe shall be permitted to be reinforced with glass fibers.

2-16.3.2 The foam-liquid concentrate piping shall be adequately sized to allow the maximum required flow rate and shall be arranged to prevent water from entering the foam tank.

2-16.4 Foam-Liquid Proportioning Systems.

2-16.4.1 The foam concentrate proportioning system shall provide a preset or adjustable means of controlling the ratio of foam concentrate to the quantity of water in the foam solution being discharged from all orifices normally used for aircraft fire-fighting operations.

2-16.4.2 The proportioning system shall be sufficiently accurate to provide for the discharge of finished foam within the range specified in NFPA 412, *Standard for Evaluating Aircraft Rescue and Fire Fighting Foam Equipment*.

2-16.5 Turret Nozzles.

2-16.5.1 Major aircraft rescue and fire-fighting vehicles shall have one or two primary turret nozzles. The primary turret nozzle(s) shall meet the requirements of 2-16.5.2 and 2-16.5.3.

2-16.5.2 The total foam solution discharge rate from the primary turret, or pair of primary turrets, shall be as specified in Table 2-16.5.2. The primary turret nozzles shall include roof turret(s), extendable turret nozzles, and bumper turrets.

Table 2-16.5.2 Turret Flow Rates

Vehicle Class	Rated Tank Capacity		Minimum Turret(s) Capacity Required		Roof Turret with Bumper Turret Flow Rates				Roof Turret without Bumper Turret	
					Roof		Bumper			
	(gal)	(L)	(gpm)	(lpm)	(gpm)	(lpm)	(gpm)	(lpm)	(gpm)	(lpm)
1	1000	3785	750	2838.8	500	1892.5	250	946.3	500	1892.5
2	1500	5677.5	750	2838.8	500	1892.5	250	946.3	750	2838.8
3	2500	9462.5	1250	4731.3	1000	3785	250	946.3	1250	4731.3
4	3000	11,355	1250	4731.3	1000	3785	250	946.3	1250	4731.3
5	4000	15,140	1250	4731.3	1000	3785	250	946.3	1250	4731.3
6	5000	18,925	1250	4731.3	1000	3785	250	946.3	1250	4731.3

7	6000	22,710	1250	4731.3	1000	3785	250	946.3	1250	4731.3

For Classes 3 through 7 vehicles, the minimum combined rated turret discharge capacity shall be at least 1250 gpm (4731 lpm).

2-16.5.3 A turret(s) shall be capable of discharging foam as specified in Table 2-16.5.3 in still air in a continuously variable pattern with the turret(s) elevated to the maximum stream reach position.

Table 2-16.5.3 Turret Requirements

Vehicle Class	Straight Stream Minimum Range Far Point		Dispersed Stream Minimum Width		Dispersed Stream Minimum Range Far Point	
	(ft	m)	(ft	m)	(ft	m)
1	160	49	35	10	60	18
2	190	58	35	10	65	20
3	230	70	35	10	70	21
4	250	76	35	10	75	23
5	250	76	35	10	75	23
6	250	76	35	10	75	23
7	250	76	35	10	75	23

2-16.5.4 Turret nozzles with liquid flow rates of 750 gpm (2839 lpm) or more shall be of the dual discharge type and arranged to allow selection of either 50 percent or 100 percent of the turret capacity. The roof turret discharge rates shall have a tolerance of +10 percent/–0 percent.

2-16.5.5 Turrets shall be permitted to be operated manually or to be power controlled. Where turret remote control is provided in the cab, operation shall be less than 30 lbf (13.6 kgf), and cab indication of turret elevation and azimuth shall be provided. Manual override of all fixed, mounted, roof turret controls shall be provided inside the cab for all power controlled turrets, and manual override operation shall be less than 30 lbf (13.6 kgf). Where turret control is at the platform, operation shall be less than 50 lbf (22.7 kgf). All power-assisted controls shall have identical operating characteristics.

2-16.5.6 Turrets shall be capable of being elevated at least 45 degrees above the horizontal and shall be depressed to discharge agent within 30 ft (9.1 m) in front of the vehicle at full output using a dispersed stream. Where a single turret is used on a vehicle, it shall be capable of being rotated not less than 105 degrees to either side, with total traverse not less than 210 degrees. Where two turrets are used on a vehicle, suitable stops shall be provided so that neither turret can interfere with the other turret.

2-16.5.7* If the primary turret is of the extendable type, it shall meet the following design and functional requirements:

(a) It shall comply with NFPA 1901, *Standard for Pumper Fire Apparatus*, Section 8-5, 8-5.2, and 8-5.3, and shall meet the requirements of 2-2.1.3 and 2-2.1.4 of this standard while in the stowed position. It shall achieve a 20-percent side slope with the extendable turret fully elevated and the nozzle rotated uphill at maximum horizontal rotation while discharging at maximum flow rate. The vehicle shall be provided with an interlock or warning system and placards in full view of the driver/operator to provide the operational limitations during all phases of operation.

Exception: Flow rates shall be in accordance with Table 2-16.5.2 for major vehicles.

(b) The extendable turret shall function without the use of outriggers or other ground contact stabilizers.

(c) The primary turret shall achieve the elevation and reach needed to service the highest tail-mounted engine for the aircraft being protected.

(d) The extendable turret shall function as a conventional roof turret in accordance with 2-16.5.2 for major vehicles.

(e) The extendable turret shall be capable of applying agent to the interior of the aircraft through cargo bay openings, passenger doorways, and emergency exits on the type of aircraft being protected while the aircraft is in either the gear up or gear down landing position.

2-16.6 Preconnected Hand Lines.

Preconnected hand lines shall be those hand lines for discharging foam streams that are specified by the purchaser as intended for use as primary crash/fire/rescue attack equipment. All other hand lines that are installed on the vehicle for discharging either water or foam, or both, shall be considered as additional hand lines and not preconnected hand lines.

Each preconnected hand line compartment shall be located so that the distance between the hand line nozzle and the ground, step, or deck plate upon which the operator stands to initiate the pulling of the hand line from the reel or the top lay of the woven jacket hose is not more than 6 ft (1.8 m) above that surface.

2-16.6.1 Major aircraft rescue and fire-fighting vehicles shall have a minimum of two preconnected hand lines that meet the requirements of either 2-16.6.3 or 2-16.6.4. The two preconnected hand lines shall not be located on the same side of the vehicle.

2-16.6.2 The purchaser shall specify either two reeled hand lines as specified in 2-16.6.3 or two woven jacket hand lines as specified in 2-16.6.4 or one of each.

2-16.6.3 Reeled Hand Lines.

2-16.6.3.1 Hand lines for reels shall have a minimum internal diameter of 1 in. (25.4 mm), shall have a minimum burst pressure rating three times the nominal working pressure of the system, and shall be able to discharge the flow required in 2-16.6.3.3 without unreeling the hose.

2-16.6.3.2 At least 100 ft (30.5 m) of hose shall be provided for each reel.

2-16.6.3.3 Each hand line shall be equipped with a shutoff-type nozzle designed to discharge both foam and water at a nominal discharge rate of 60 gpm (227.1 lpm), +10 percent/–0 percent.

Each nozzle shall have minimum foam discharge patterns from a dispersed stream of 15 ft (4.6 m) in width and 20 ft (6.1 m) in range to a straight foam stream with a 50-ft (15.2-m) range.

2-16.6.3.4 Each hose reel shall have capacity for at least 100 ft (30.5 m) of 1-in. (25.4-mm) hose or more if specified by the purchaser.

2-16.6.3.5 Each hose reel shall be designed and positioned to allow hose reel removal by a single person from any position in a 120-degree horizontal sector. Each hose reel shall be equipped with a friction brake to prevent the hose from unreeling when not desired. A power rewind with manual override shall be provided. The nozzle holder, friction brake, rewind controls, and manual valve control shall be accessible from the ground.

2-16.6.3.6 The discharge control to each hand line shall be adjacent to the hand line and accessible to the person using the hand line.

2-16.6.4 Woven Jacket Hand Lines.

2-16.6.4.1 Woven jacket hand lines shall have a minimum diameter of $1^1/_2$ in. (38.1 mm) and shall meet the requirements of NFPA 1961, *Standard for Fire Hose*.

2-16.6.4.2 At least 150 ft (45.7 m) of hose shall be provided for each hand line.

2-16.6.4.3 Each hand line shall be equipped with a shutoff-type nozzle designed to discharge both foam and water at a nominal discharge rate of 95 gpm (359.6 lpm), ±5 percent. Each nozzle shall have minimum foam discharge patterns from a dispersed stream of 15 ft (4.6 m) in width and 20 ft (6.1 m) in range to a straight foam stream with a 65-ft (19.8-m) range.

2-16.6.4.4 Each hand line shall be stored in a hose compartment and shall be preconnected. Each hose compartment shall have a capacity for a minimum of 150 ft (45.7 m) of $1^1/_2$-in. (38.1-mm) multiple jacket hose or more if specified by the purchaser.

2-16.6.4.5 Hose compartments shall be fabricated from noncorrosive material and shall be designed to drain effectively. The compartment shall be smooth and free from all projections that might damage the hose. No other equipment shall be mounted or located where it can obstruct the removal of the hose.

2-16.6.4.6 The discharge control to each hand line shall be adjacent to the hand line and accessible to the person using the hand line.

2-16.7 Bumper Turret, Ground Sweep, and Undertruck Nozzles.

2-16.7.1 Vehicles shall have a remote-controlled bumper turret or ground sweep nozzle(s) mounted on the front of the vehicle. Controls for the bumper turret or ground sweep nozzle(s) shall be mounted inside the cab within easy reach of the driver and a crew person.

2-16.7.1.1 The bumper turret shall have a horizontal rotation of 180 degrees, +10 percent/-0 percent, and vertical travel of +45 degrees/-20 degrees. The flow rate shall be 250 gpm (946.3 lpm), +10 percent/–0 percent.

2-16.7.1.2 The ground sweep nozzle(s) shall have a total discharge rate of 100 gpm (378.5 lpm), +10 percent/–0 percent. The minimum reach requirements are as follows:

Minimum reach	30 ft (9.1 m)
Minimum pattern width	12 ft (3.7 m)

2-16.7.2 Where specified, two or more undertruck nozzles shall be mounted under the truck and controlled from the cab. A sufficient number shall be provided to protect the bottom of the vehicle and the inner sides of the wheels and tires with foam solution discharged in a spray pattern.

2-16.8 Foam Quality.

Turrets, hand lines, and ground sweeps shall discharge foam having the quality specified in NFPA 412, *Standard for Evaluating Aircraft Rescue and Fire Fighting Foam Equipment*.

Measurement of the expansion ratio and 25-percent drainage times shall be in accordance with the procedures outlined in NFPA 412.

2-17 Auxiliary Agent System.

Where specified, the vehicle shall be equipped with an auxiliary agent system using either dry chemical (potassium bicarbonate) or Halon 1211. The minimum capacity of the auxiliary agent system shall be 450 lb (204.3 kg) of potassium bicarbonate for all classes of vehicles.

2-17.1 Dry Chemical Container.

The dry chemical container shall be constructed in accordance with the ASME *Boiler and Pressure Vessel Code*, Section 8, and shall be so stamped.

2-17.1.1 All piping and fittings shall conform to the appropriate ASME code and shall be designed to withstand the working pressure of the system. The design of the piping and valving shall provide the desired flow of gas into the system and the minimum amount of restriction from the chemical container(s) to the hose connection. Where more than one hose line is provided, piping and fittings shall be sized and designed so that there is equal flow to each line, regardless of the number of lines placed in operation.

2-17.1.2 Provisions shall be made for purging all piping and hose of dry chemical after use without discharging the dry chemical remaining in the dry chemical container(s). Provisions also shall be made for the depressurization of the dry chemical container(s) without the loss of the remainder of the dry chemical. A pressure gauge shall be provided that indicates the internal pressure of the agent storage container(s) at all times.

2-17.1.3 The system shall be designed to ensure fluidization of the dry chemical at the time of operation. Where any design includes the movement of the chemical container(s) to fluidize the contents, such design also shall include a manual operating feature.

2-17.1.4 A check valve shall be provided in the gas piping to prevent the extinguishing agent from being forced back into the propellant gas line.

2-17.1.5 A means of pressure relief conforming to appropriate ASME codes shall be provided for the dry chemical container and piping to prevent overpressurization in the event of a malfunction in the propellant gas regulator system or in the event the container is involved in a severe fire exposure.

2-17.1.6 The fill opening in the dry chemical container shall be located so that it is easily accessible for recharging and necessitates a minimum amount of time and effort to open and close. Filling shall be accomplished without the removal of any of the extinguisher piping or any major component.

2-17.1.7 A quick-acting control to be operated by the driver to pressurize the dry chemical agent system from the cab of the vehicle shall be provided, with a similar control at the hand line.

2-17.2 Propellants.

2-17.2.1 The propelling agent shall be dry nitrogen or dry air.

2-17.2.2 All propellant gas cylinders and valves shall be in accordance with U.S. Department of Transportation (DOT) requirements or regulations. Cylinders shall bear the DOT marking.

2-17.2.3 The method of adequately pressurizing and propelling the dry chemical in the system shall provide a sufficient quantity of gas to expel the agent, as well as allowing the complete purging of all piping and hose lines after each use.

2-17.2.4 The design of the propellant source shall provide for quick and easy replacement after each use.

2-17.2.5 A pressure gauge shall be provided and shall indicate the pressure on the propellant gas source at all times.

2-17.2.6 Cylinder valves, gauges, and piping shall be arranged to preclude accidental mechanical damage.

2-17.3 Pressure Regulation.

2-17.3.1 Pressure regulation shall be designed to reduce the normal cylinder pressure automatically and to hold the propellant gas pressure at the designed operating pressure of the dry chemical container(s).

2-17.3.2 All pressure regulating devices shall be sealed or pinned at the designed operating pressures after final adjustment by the system manufacturer.

2-17.3.3 Pressure regulating devices shall be equipped with a spring-loaded relief valve that relieves any excess pressure that develops in the regulator.

2-17.3.4 The pressure regulator shall be permitted to be of a type without pressure indicating gauges.

2-18 Halon 1211 System.

2-18.1 Halon Container.

2-18.1.1 The storage container shall be designed for pressurization and shall be constructed in accordance with the ASME *Boiler and Pressure Vessel Code* and shall be so marked.

2-18.1.2 The material of construction shall be resistant to corrosion by the halon agent to be stored.

2-18.1.3 A readily accessible charge coupling of sufficient size to allow ease in filling shall be provided. Filling shall be accomplished without the removal of any of the extinguisher piping or any major component. A pressure gauge shall be provided that indicates the internal pressure of the agent storage containers at all times.

2-18.1.4 A means shall be provided to determine the contents of the container as a guide in recharging partial loads and to prevent overfilling of the tank.

2-18.2 Propellant Gas.

2-18.2.1 The propellant gas shall be dry nitrogen or dry compressed air and shall be provided in sufficient quantity to expel the halon agent as well as to purge all piping and hose lines after use.

2-18.2.2 All propellant gas cylinders and valves shall be in accordance with U.S. Department of Transportation (DOT) requirements or regulations. Cylinders shall bear the DOT marking.

2-18.2.3 Pipes and valves connected to the halon container shall conform to the appropriate ASME code and shall be designed to withstand the working pressure of the system.

2-18.2.4 The design of the propellant source shall provide for quick and easy replacement after each use.

2-18.2.5 A pressure gauge shall be provided and shall indicate the pressure of the propellant gas source at all times.

2-18.2.6 Cylinder valves, gauges, and piping shall be arranged to preclude accidental mechanical damage.

2-18.2.7 A check valve shall be provided in the gas piping to prevent the liquid agent from being forced back into the propellant gas line.

2-18.3 Pressure Regulation.

2-18.3.1 An ASME-approved pressure relief valve of adequate capacity shall be provided on the container and shall be set to prevent pressures in excess of the maximum design working pressure.

2-18.3.2 Pressure regulation shall be designed to reduce the normal cylinder pressure automatically and to hold the propellant gas pressure at the designed operating pressure of the halon container(s).

2-18.3.3 All pressure regulating devices shall be sealed or pinned at the designed operating pressures after final adjustment by the system manufacturer.

2-18.3.4 Pressure regulating devices shall be equipped with a spring-loaded relief valve that relieves any excess pressure that develops in the regulator.

2-18.3.5 The pressure regulator shall be permitted to be of a type without pressure indicating gauges.

2-18.4 Halon Delivery Piping and Valves.

2-18.4.1 All piping, couplings, and valves shall be sized for necessary flow with minimum restriction and pressure loss. Material for all piping, couplings, and valves shall be selected to avoid corrosive and galvanic action. Piping shall be mounted securely and provided with flexible couplings to minimize stress.

2-18.4.2 All valves shall be of the quarter-turn type and shall be selected for ease of operation and freedom from leakage.

2-18.4.3 All discharge piping shall be tested at 50 percent above the system operating pressure.

2-18.4.4 Where more than one hose line is provided, piping and fittings shall be sized and designed so that there is equal flow to each line, regardless of the number of lines placed in operation.

2-18.4.5 Provisions shall be made for purging all piping and hose of the halon after use without discharging the halon remaining in the container(s). Provisions also shall be made for venting of the halon container without loss of the remainder of the liquid agent.

2-18.4.6 A quick-acting control to be operated by the driver to pressurize the halon system from the cab of the vehicle shall be provided, with a similar control at the hand line.

2-19 Dry Chemical Turret.

2-19.1 Auxiliary Agent Discharge.

Where specified, a primary turret shall have an auxiliary agent discharge mounted parallel to the primary agent discharge so that the auxiliary agent discharge is controlled the same way, and with the same travel requirements, as the primary turret.

2-19.1.1 The dry chemical minimum discharge rate from the turret shall be ≥ 16 lb/sec to ≤ 22 lb/sec (≥ 7.3 kg/sec to ≤ 10 kg/sec). The minimum far point reach for dry chemical shall be 100 ft (30.5 m), and the minimum width shall be 17 ft (5.2 m).

2-19.1.2 The dry chemical system shall be designed so that the operator can select to discharge both the primary and the auxiliary agent systems separately or simultaneously.

2-19.2 Auxiliary Agent Hand Lines.

2-19.2.1 Hand lines for auxiliary agents shall have a minimum burst pressure rating three times the nominal working pressure of the system and meet the requirements specified below. The auxiliary agent hand line shall be equipped with a nozzle that allows a fully opened to a fully closed position in a single, simple movement and shall be designed to discharge agent at a minimum rate of ≥ 5 lb/sec to ≤ 7 lb/sec (≥ 2.3 kg/sec to ≤ 3.3 kg/sec) at a minimum range of 20 ft (6.1 m). Nozzle construction shall be of nonferrous metal or stainless steel.

2-19.2.2 Twinned hand lines and nozzles shall be designed so that each agent can be discharged separately or simultaneously. The barrels shall be linked together to provide coordinated application by one operator.

2-19.2.2.1 Each reel shall have capacity for at least 100 ft (30.5 m) of 1-in. (25.4-mm) hose or more if specified by the purchaser.

2-19.2.2.2 Each reel shall be designed and positioned to allow hose line removal by a single person from any position in a 120-degree horizontal sector. Each reel shall be equipped with a friction brake to prevent the hose from unreeling when not desired. A power rewind with manual override shall be provided. The nozzle holder, friction brake, rewind controls, and manual valve control shall be accessible from the ground.

2-20 Lighting and Electrical Equipment.

2-20.1

Lighting equipment shall be installed in conformity with local road regulations, where practicable, and shall include the following:

(a) Headlights with upper and lower driving beams. A control switch that is readily accessible to the driver shall be provided for beam selection.

(b) Dual taillights and stoplights.

(c) Self-canceling turn signals, front and rear, with a steering column-mounted control and a visual and audible indicator. A four-way flasher switch shall be provided.

(d) Where specified, a minimum 6-in. (152.4-mm) spotlight on both left and right sides of the windshield, hand-adjustable type, with controls for beam adjustment inside the truck cab.

(e) Where specified, a minimum 6-in. (152.4-mm) spotlight mounted on a turret nozzle with a control switch that is readily accessible to the driver.

(f) Adequate reflectors and marker and clearance lights furnished to describe the overall length and width of the vehicle.

(g) Engine compartment lights, nonglare type, arranged to illuminate both sides of the engine, with individual switches located in the engine compartment. Service lighting shall be provided for all areas described in 2-12.2(a), (b), and (c), as well as for the engine compartment.

(h) Lighting provided for all top deck working areas.

(i) At least one back-up light and an audible alarm with a minimum of 97 dBA meeting SAE J994, *Standard on Alarm-Backup-Electric Laboratory Performance Testing*, installed in the rear of the body.

(j) A flashing red beacon or alternate red and white flashing lights mounted on the top deck and visible for 360 degrees in the horizontal plane. The mounting of the beacon also shall provide good visibility from the air. A control switch shall be provided on the instrument panel in the cab for control of the beacon.

2-20.2*

A warning siren shall be provided that has a sound output of not less than 95 dBA at 100 ft (30.5 m) when measured directly ahead of the siren and not less than 90 dBA at 100 ft (30.5 m), measured at 45 degrees on either side. The siren shall be mounted to allow maximum forward sound projection but shall be protected from foam dripping from the turret or water splashed up by the tires.

2-20.3

A horn shall be provided and shall be mounted at the front part of the vehicle with the control positioned so that it is readily accessible to the driver.

2-20.4

A master switch for all emergency lights shall be provided.

2-20.5 Radios.

2-20.5.1 Provision shall be made for mounting radios. Operation of the radios shall be from the cab. Radios shall be mounted to allow quick servicing or replacement.

2-20.5.2 The purchaser shall specify all necessary radios and frequencies that are to be provided.

2-20.6

Where furnished, air horns, an electric siren(s), and an electronic siren speaker(s) shall be mounted as low and as far forward on the apparatus as practical. Audible warning equipment shall not be mounted on the roof of the apparatus.

2-20.7

The purchaser shall specify whether a manually operated or a power-assisted turret shall be provided. Where a manually operated turret is specified, controls shall be in the cab, operation force shall be less than 30 lbf (13.6 kgf), and an indication of turret elevation and azimuth shall be provided. Where a power-assisted turret is specified, controls shall be in the cab, operation forces shall be less than 30 lbf (13.6 kgf), an indication of turret elevation and azimuth shall be provided, and a manual override of all roof turret functions shall be provided in the cab. The manual override operation force shall be less than 30 lbf (13.6 kgf). Where turret control is at the platform, operation forces shall be less than 50 lbf (22.7 kgf).

2-21* Tools.

Provision shall be made for mounting tools and equipment, as specified by the purchaser, on the truck. Special tools for servicing the vehicle, fire suppression system, and any of the auxiliary equipment shall be furnished as necessary by the vehicle manufacturer.

Chapter 3 Combined Agent Vehicles

3-1 General.

3-1.1

The category of combined agent vehicles shall encompass the range of water capacity commencing at 100 gal (378.5 L) and extending to 500 gal (1892.5 L). In addition to carrying foam as a primary agent, either dry chemical or Halon 1211 extinguishing agent also shall be carried as an auxiliary agent.

3-1.2

The following quantities of water and auxiliary agent shall establish the class of vehicle:

Table 3-1.2 Combined Agent Vehicle Classes

	Minimum Water Capacity		Minimum Auxiliary Agent	
Class	(gal)	(L)	(lb)	(kg)
1	100	400	450	204.3
2	200	800	450	204.3
3	300	1200	450	204.3
4	500	2000	450	204.3

3-2 Weights and Dimensions.

3-2.1 Weights.

3-2.1.1 The gross vehicle weight rating of the chassis as furnished shall equal or exceed the actual gross weight of the fully loaded and equipped vehicle.

3-2.1.2 The weight shall be distributed as equally as practical over the axles and tires of the fully loaded vehicle. The difference in weight between tires on any axle shall not exceed 5 percent of that axle weight, and the difference in weight between axles shall not exceed 15 percent of the weight of the heaviest axle. The front axle shall not be the heaviest axle. Under no circumstances shall the axle and tire manufacturers' ratings be exceeded.

3-2.1.3 The vehicle's center of gravity shall be kept as low as possible under all conditions of loading. The vehicle shall be capable of operations on a 20-percent side slope in both directions and shall be capable of ascending and descending a 50-percent grade in forward gear. Classes 1, 2, and 3 vehicles shall stand on a 30-degree side slope, and Class 4 vehicles shall stand on a 28-degree side slope. They shall be capable of ascending and descending at grades of 58 percent and 53 percent, respectively.

3-2.1.4 The vehicle also shall be driven on a steering pad around a circle with a radius of 100 ft (30.5 m). The steering wheel rotation shall increase with accelerating speed to ensure that the vehicle does not exhibit oversteer characteristics. A speed of 25 mph (40.2 km/h) shall be obtained for all classes of vehicles.

3-2.2 Dimensions.

3-2.2.1 Underchassis clearance of the vehicle shall allow mobility in soft soils and rough terrain. The minimum dimensions shall be as follows:

(a) Angle of approach — 30 degrees;

(b) Angle of departure — 30 degrees;

(c) Interaxle clearance angle — 12 degrees;

(d) Underaxle clearance — 8-in. (20.3-cm) underaxle differential housing bowl;

(e) Underbody clearance, Classes 1, 2, and 3 – 13 in. (33.0 cm);

(f) Underaxle clearance, Class 4 – $10^1/_2$ in. (26.7 cm);

(g) Underbody clearance, Class 4 – 18 in. (45.7 cm).

3-2.2.2* The overall height, length, and width of the vehicle shall be held to a minimum consistent with the best operational performance of the vehicle and the design concepts needed to achieve this performance and to provide optimum maneuverability and facilitate movement on public highways.

3-2.2.3 The vehicle shall be constructed so that a seated driver, having an eye reference point of $31^3/_4$ in. (80.7 cm) above the seat cushion and 12 in. (30.5 cm) forward from the seat back, shall be able to see the ground 20 ft (6.1 m) ahead of the vehicle and shall have a field of vision of at least 5 degrees above the horizontal plane. The field of vision in the horizontal plane shall be at least 90 degrees on each side from the straight ahead position.

3-2.2.4 Adjustable rear view mirrors with a glass area of not less than 60 in.^{2} (387 cm^2) shall be provided on each side of the vehicle. Each side shall be provided with a minimum 7-in.^{2} (45.2-cm^2) wide angle (convex) mirror.

Exception: In lieu of mirrors, audiovisual devices that meet or exceed the field of vision provided by the wide angle mirrors shall be permitted.

3-3 Engine.

3-3.1 Performance Requirements.

3-3.1.1 The vehicle engines shall have sufficient horsepower, torque, and speed characteristics to meet and maintain all vehicular performance characteristics specified in this standard. The engine manufacturer shall certify that the installed engine is approved for this application.

3-3.1.2* The fully loaded vehicle shall be able to accelerate consistently from 0 mph to 50 mph (0 km/h to 80.5 km/h) on dry, level concrete pavement at the operational airport within the times specified in Table 3-3.1.2. The maximum speed shall not be less than 65 mph (104.6 km/h). If any vehicle accelerates from 0 mph to 50 mph (0 km/h to 80.5 km/h) in less than 20 seconds, it shall meet the tilt table parameters of 35 degrees side slope as a minimum for all classes.

The acceleration times provided in Table 3-3.1.2 shall be achieved with the engine and transmission at their normal operating temperature at any ambient temperature from 0°F to 110°F (-17.8°C to 43.3°C) and at elevations up to 2000 ft (609.6 m) above sea level unless a higher elevation is specified.

For airports above 2000 ft (609.6 m), the elevation at which the vehicle shall operate in order to ensure the necessary performance shall be specified.

Table 3-3.1.2 Acceleration Times for Combined Agent Vehicles

Vehicle Class	Maximum Acceleration Time 0 mph to 50 mph (0 km/h to 80 km/h) (sec)
1	25
2	30
3	30
4	30

3-3.1.3 Where the engine is used to power both the vehicle and a fire-fighting pump, provision shall be made to ensure that the operation of the pump does not cause the following:

(a) Stalling of the engine;

(b) Pump speed in excess of that recommended.

3-3.2 Engine Cooling Systems.

3-3.2.1 Liquid-Cooled Engines. An engine coolant preheating device shall be provided as an aid to rapid starting and high initial engine performance. This device shall be fitted with a thermostat.

3-3.2.1.1 The cooling system shall be designed so that the stabilized engine coolant temperature remains within the engine manufacturer's prescribed limits under all operational conditions and at all ambient temperatures encountered at the operational airport. The cooling system shall be provided with automatic thermostat for rapid engine warming.

3-3.2.1.2 Where specified, radiator shutters, where furnished for cold climates, shall be of the automatic type and shall be designed to open automatically upon failure.

3-3.2.2 Air-Cooled Engines. Air-cooled engines shall be designed so that the stabilized cylinder head and oil temperatures remain within the engine manufacturer's prescribed limits under all operational conditions and at all ambient temperatures encountered at the operational airport.

3-3.3 Fuel System.

3-3.3.1 A complete fuel system installed with the engine manufacturer's approval shall include a fuel pump, fuel filtration, and flexible fuel lines, where necessary, that shall be protected from damage, exhaust heat, and exposure to ground fires. Gasoline engines shall have an electric fuel pump located near the fuel tank to prevent vapor lock.

3-3.3.2 Accessible filtration shall be provided for each fuel supply line, and a drain shall be provided at the bottom of the fuel tank.

3-3.3.3 Fuel tanks shall not be installed in a manner that allows gravity feed.

3-3.3.4 Fuel tanks shall have a minimum capacity of 18 gal (68.1 L).

3-3.4 Exhaust System.

3-3.4.1 The exhaust system shall be of a size that avoids undue back pressure and shall be located and constructed in such a manner that entrance of exhaust gases into the cab is minimized under all conditions of operation. The exhaust system shall be of high-grade, rust-resistant materials.

3-3.4.2 The tail pipe and muffler shall be protected from damage that could result from traversing rough terrain. The tail pipe shall be designed to discharge upward or to the rear and shall not be directed toward the ground.

3-4 Vehicle Electrical System.

3-4.1

The engine shall be equipped with a complete battery starting system.

3-4.2

A complete 12-volt, negative electrical system including transistorized alternator and fully transistorized voltage regulator shall be furnished. The idle minimum charging rate shall be 30 amperes. The alternator shall be driven by dual belts.

3-4.2.1 For 12-volt systems, the batteries shall be connected so that their capacity meets the cold-cranking performance amperes at 0°F (–17.8°C) to comply with the engine manufacturer's recommendations. In addition to the cold-cranking performance ampere requirements, a minimum reserve capacity of 600 minutes at 80°F (26.7°C) shall be provided.

3-4.2.2 For 24-volt systems, the batteries shall be connected so that their capacity meets the cold-cranking performance amperes at 0°F (–17.8°C) to comply with the engine manufacturer's recommendations.

3-4.3

Batteries shall be mounted securely and adequately protected against physical injury and vibration, water spray, and engine and exhaust heat. Where an enclosed battery compartment is provided, it shall be ventilated adequately, and the batteries shall be readily accessible for examination, test, and maintenance.

3-4.4 Battery Capacity.

3-4.4.1 Battery capacity shall be commensurate with the size of the engine and the anticipated electrical load. The capacity shall be not less than a rating of 120 ampere-hours at a 20-hour discharge rate (520 cold-cranking amperes) for gasoline engines and a rating of 200 ampere-hours at a 20-hour discharge rate (900 cold-cranking amperes) for diesel engines using 12-volt starting systems. One or more polarized receptacles shall be provided for charging all batteries.

3-4.4.2 Battery capacity and wiring circuits, including the starter switch and circuit and the starter to battery connections, shall meet or exceed the manufacturer's recommendations. A master power disconnect system shall isolate power from all of the electrical system except the primary power circuits to the alternator and starter. Exceptions apply only to systems that are required to operate when the vehicle is not attended. The control device shall be accessible from the driver's seated position.

3-4.4.3 Where specified, an on-board battery charger/conditioner shall be provided on the vehicle and shall have a minimum output rating of one-half percent of the cold-cranking ampere rating at 32°F (0°C) of the engine-starting battery system. The battery charger shall be supplied from an external power source of 115 volts or 220 volts AC. This battery charger/conditioner shall be the type that can be connected to the batteries at all times and yet maintain a charge to the batteries without causing any damage. The unit shall reduce its charging output level to a point where a small amount of charge is allowed to the batteries continuously or it shall shut off completely. The charger/conditioner shall have protection built into it to protect it from damage during high current demands such as those caused by starting the engine. The unit shall be provided with a grounded AC receptacle to allow a pull-away connection from the local electrical power supply to the battery charger/conditioner.

3-4.5

The electrical system and its components shall be weatherproof, insulated, and protected from chafing, damage from road debris, and exposure to ground fires. All wiring shall be coded to correspond with the wiring diagram provided with the vehicle. Circuit protection shall be provided to protect the vehicle in the event of electrical overload.

3-4.6

Radio suppression of the electrical system shall be in accordance with SAE J551, *Standard on Performance Levels and Methods of Measurement of Electromagnetic Radiation from Vehicles and Devices (30-1000 MHz)*, or an equivalent radio suppression standard.

3-5 Vehicle Drive.

3-5.1

Transmission of power from the engine to the wheels of the vehicle shall be through a torque converter and an automatic or a semiautomatic gearbox. The entire drive train shall be designed and rated by the component manufacturer as having sufficient capacity to slip the wheels of the static-loaded vehicle on a surface having a coefficient of friction of 0.8. A range of gears providing the specified top speed and a grade ability of 50 percent shall be provided with sufficient intermediate gears to achieve the specified acceleration.

3-5.2

A positive drive shall be provided to each wheel by means of a fully locked driveline in order to maximize traction on low-friction surfaces. Positive drive shall be permitted to be achieved either by the use of automatic locking and torque proportioning differentials or shall be permitted to be selected manually by the seated driver by use of a single control while the vehicle is in motion.

3-5.3

All-wheel drive on these vehicles shall incorporate a drive to the front and rear axles that is engaged at all times during the intended airport service. An interaxle differential shall be installed with automatic means or driver-selected means of differential locking.

3-5.4

All traction-increasing devices shall be operated by a single control for driving simplicity.

3-5.5

Front and rear axles shall have adequate capacity to carry the maximum imposed load under all intended operating conditions. The variations in axle tread shall not exceed 20 percent of the tire sectional width at rated load.

3-6 Suspension.

The suspension system shall be designed to allow the loaded vehicle to perform as follows:

(a) Travel at the specified speeds over improved surface;

(b) Travel at moderate speeds over unimproved surface;

(c) Provide diagonally opposite wheel motion 10 in. (25.4 cm) above ground obstacles without raising the remaining wheels from the ground;

(d) Prevent damage to the vehicle caused by wheel movement; and

(e) Provide a good environment for the crew when traveling over all surfaces.

3-7 Wheels, Tires, and Rims.

3-7.1

Vehicles shall be required to have off-highway mobility while meeting the specified paved surface performance.

3-7.2

Tires shall be selected to maximize the acceleration, speed, braking, and maneuvering capabilities of the vehicle on paved surfaces without sacrificing performance on all reasonable terrains found within the airport boundary.

3-7.3*

The purchaser shall provide a tire description that reflects the off-road performance requirements necessitated by the soil conditions encountered at the operational airport. Soil conditions that vary from an extremely fine grain soil or clay to an extremely coarse grain soil, sand, or gravel in a dry, saturated, or frozen condition shall be considered.

To optimize flotation under soft ground conditions, tires of larger diameter or width, or both, than is needed for bearing weight only shall be specified. Similarly, the lowest tire pressure compatible with the high speed performance requirements also shall be specified.

3-7.4

Vehicle and tire manufacturers shall be consulted for the tread design most suitable for the specific soil composition at individual airports.

3-7.5

All wheels on the vehicle shall be of the single-wheel type with all rims, tires, and wheels of an identical size and the same tire tread design.

3-7.6

Rims, tires, wheels, and inflation pressures shall be approved by their respective manufacturers as having sufficient capacity to meet the specified performance and shall be certified for not less than 5 mi (8 km) of continuous operation at 65 mph (104.6 km/h) at normal operational pressure.

3-8 Towing Connections.

At least two large tow eyes or tow hooks (one at the front and one at the rear), capable of towing the vehicle on level ground without damage, shall be mounted on the truck and attached directly to the frame structure or where recommended by the vehicle manufacturer.

3-9 Brakes.

3-9.1*

Service brakes shall be of the all-wheel type. Service brakes shall be permitted to be of the hydraulic type with power booster or of the air-mechanical type.

3-9.2

If air-mechanical brakes are furnished, a brake chamber shall be provided for each wheel and shall be mounted so that no part of the brake chamber projects below the axle bowl.

3-9.3

Air brake systems shall include a compressor, an automatic air-drying system immediately downstream from the compressor to prevent condensation buildup in all pneumatic lines, a release valve, a brake control valve, a treadle-type actuating pedal, an air pressure gauge, enclosed-type brake adjusters, low pressure warning, and all necessary connections.

3-9.4

The compressor shall have the capacity for quick buildup of tank pressure from 0 psi (0 kPa) to the pressure to release spring brakes, and this buildup in pressure shall be accomplished within 15 seconds.

3-9.5 Compressed Air Reservoirs.

3-9.5.1 Compressed air reservoirs shall have a minimum capacity of 2000 $in.^3$ (3 277 400 cm^3) and shall be equipped with drain and safety valves.

3-9.5.2 Provision shall be made for charging of air tanks with either a pull-away electrical connection used to power a vehicle-mounted auxiliary compressor or a pull-away air connection for charging of air tanks from an external air source.

3-9.6

The service brakes shall be capable of holding the fully loaded vehicle on a 50-percent grade and shall be capable of bringing the fully loaded vehicle to five complete successive stops within 35 ft (10.7 m) at a speed of 20 mph (32.2 km/h) on dry, hard, approximately level road that is free from loose material.

3-9.7*

The parking brake system shall be an entirely independent mechanical system or shall be permitted to be connected to the same brake shoes as the service brakes but through entirely separate mechanical means.

3-9.8

The parking brake shall be capable of holding the fully loaded vehicle on a 20-percent grade.

3-9.9

An emergency brake system shall be provided that is applied and released by the driver from the cab and is capable of modulation by means of the service brake control. When a single failure in the service brake system of a part designed to contain compressed air or brake fluid occurs, other than failure of a common valve, manifold, brake fluid housing, or brake chamber housing, the vehicle shall stop within no more than 288 ft (87.8 m) at 40 mph (64.4 km/h) without any part of the vehicle leaving a dry, hard, approximately level roadway that has a width equal to the vehicle width plus 4 ft (1.2 m).

3-10 Steering.

3-10.1

The chassis shall be equipped with power-assisted steering with direct mechanical linkage from the steering wheel to the steered axle(s) to allow manual control in the event of power-assist failure.

3-10.2

The power steering system shall have sufficient capacity so that no more than 15 lbf (66.7 N) pull is needed on the steering wheel rim in order to turn the steering linkage from stop to stop with the fully loaded vehicle stationary on a dry, level, paved surface with the engine at idle.

3-10.3

The wall-to-wall turning diameter of the fully loaded vehicle shall be less than three times the vehicle length.

3-11 Cab.

3-11.1

The cab shall be fully enclosed (i.e., floor, roof, and four sides) and mounted on the forward part of the vehicle. Seating for the crew shall be restricted to the cab. The maximum number of crew seat positions provided in the cab shall be designated by the manufacturer and so labeled in the cab. As a minimum, two designated seat positions shall be provided, one for the driver and one for an additional crew member. Seat belts approved by the authority having jurisdiction shall be provided for each of the designated seating positions. Space shall be provided for all instrument controls and equipment specified without hindering the crew. Doors that open to as wide a position as possible shall be provided on each side of the cab with the necessary steps and handrails to allow rapid and safe entrance and exit from the cab. The cab design shall take into consideration the provision of ample space for the crew to enter and exit the cab and carry out normal operations while wearing full protective equipment.

3-11.2

The cab shall meet the visibility requirements of 3-2.2.3. Interior cab reflections from exterior and interior lighting shall be minimized. The windshield shall be shatterproof safety glass, and all other windows shall be constructed of approved safety glass. The cab shall be provided with wide gutters to prevent foam and water from dripping on the windshield and side windows. Where equipped with a roof turret having manual controls above the cab roof, the cab shall be designed with a quick-access passage to the roof turret(s).

3-11.3

The cab shall be weatherproof and shall be fully insulated thermally and acoustically with a fire-resistant material. The cab interior noise level at any seated position shall not exceed 85 dBA while traveling at 50 mph (80.5 km/h) on a level, hard surface without warning devices operating. With warning devices operating, the maximum limit shall be 90 dBA. The cab shall be permitted to be of the unitized rigid body and frame structure type, or it shall be permitted to be a separate unit flexibly mounted on the main vehicle frame. The cab shall be constructed from materials of adequate strength to ensure a high degree of safety for the crew under all operating conditions, including excess heat exposure and vehicle roll-over accidents.

3-11.4 Instruments, Warning Lights, and Controls.

3-11.4.1 The minimum number of instruments, warning lights, and controls consistent with the safe and efficient operation of the vehicle chassis and fire-fighting system shall be provided. All chassis instruments and warning lights shall be grouped together on a panel immediately in front of the driver. All fire-fighting system instruments, warning lights, and controls shall be grouped together by function to provide ready accessibility as well as high visibility for the driver as well as crew members.

3-11.4.2 All instruments and controls shall be illuminated, and backlighting shall be used where practical.

3-11.4.3 Groupings of both the chassis and fire-fighting system instruments, warning lights, and controls shall be easily removable as a unit or shall be on a panel hinged for back access by the use of quick-disconnect fittings for all electrical, air, and hydraulic circuits.

3-11.4.4 The following instruments or warning lights, or both, shall be provided as a minimum:

(a) Speedometer/odometer;

(b) Engine tachometer(s), where specified;

(c) Fuel level;

(d) Air pressure, where specified;

(e) Engine(s) temperature;

(f) Pump pressure, where specified;

(g) Water tank level, where specified;

(h) Foam-liquid tank level, where specified;

(i) Low air pressure warning, where specified;

(j) Headlight beam indicator;

(k) Engine(s) oil pressure;

(l) Voltmeter(s);

(m) Transmission oil temperature.

3-11.4.5 The cab shall have all the necessary controls within easy reach of the driver for the full operation of the vehicle and for activating the fire-fighting system. The following cab controls shall be provided, as applicable:

(a) Accelerator pedal;

(b) Brake pedal;

(c) Parking brake control;

(d) Steering wheel, with self-canceling directional control signal and horn;

(e) Transmission range selector;

(f) Pump control or liquid agent pressurization control;

(g) Liquid agent tank valve control;

(h) Siren switch(es);

(i) Ignition switch(es);

(j) Auxiliary agent pressurization control;

(k) Remote turret, only where remote turret is furnished;

(l) Starter switch(es);

(m) Light switches;

(n) Windshield wiper and washer controls;

(o) Heater/defroster controls.

3-11.5 Equipment.

3-11.5.1 The following equipment shall be provided in or on the cab, as applicable:

(a) Heater/defroster;

(b) Driver's seat with fore and aft adjustment, with seat belt;

(c) Crew seats with individual retractable seat belts;

(d) Windshield washers appropriate for removing foam;

(e) Windshield wipers appropriate for removing foam;

(f) Siren;

(g) Horn;

(h) Sun visors;

(i) Outside rear view mirrors, as specified in 3-2.2.4;

(j) Interior lighting;

(k) Provisions for mounting SCBA of the type specified by the purchaser at each crew seat position.

3-11.5.2 The minimum number of instruments, warning lights, and controls consistent with the safe and efficient operation of the vehicle, chassis, and fire-fighting system shall be provided. All chassis instruments and warning lights shall be grouped together on a panel in front of the driver. All fire-fighting system instruments, warning lights, and controls shall be grouped together by function to provide ready accessibility and high visibility for the driver as well as crew members.

3-11.6

Signs that state "Occupants must be seated and wearing a seat belt when apparatus is in motion" shall be provided. Such signs shall be visible from each seated position. An accident prevention sign shall be located at the rear step area of the vehicle, if it exists. It shall warn personnel that standing on the step while the vehicle is in motion is prohibited.

3-12 Body.

3-12.1

The body shall be constructed of materials that are of the lightest weight consistent with the strength necessary for off-pavement operation over rough terrain and where exposed to excess heat. The body shall be permitted to be of the unitized-with-chassis-rigid-structure type or it shall be permitted to be flexibly mounted on the vehicle chassis. It also shall include front and rear fenders or wheel wells. Body panels shall be removable where necessary to provide access to the interior of the vehicle.

3-12.2

Access doors shall be provided for those areas of the interior of the vehicle that are inspected frequently. In particular, access doors of sufficient size and number shall be provided for access to the following:

(a) Engine;

(b) Pump;

(c) Battery storage;

(d) Fluid reservoirs;

(e) Foam system.

Other areas that need to be accessible for inspection or maintenance shall be open or shall have removable panels.

3-12.3

Suitable, lighted compartments shall be provided for convenient storage of equipment and tools to be carried on the vehicle. Compartment doors shall be operable for hands covered with bulky gloves. Compartments shall be weathertight and self-draining.

3-12.4

The working deck of the vehicle shall be reinforced adequately to allow the crew to perform its duties in all areas where access to auxiliary or installed equipment is necessary.

3-12.5

Handrails or bulwarks shall be provided where necessary for the safety and convenience of the crew. Rails and stanchions shall be braced strongly and constructed of a material that is durable and resists corrosion. Handrails shall be constructed of, or covered with, a slip-resistant material.

3-12.6

Steps or ladders shall be provided for access to the top fill area. The lowermost step(s) shall be permitted to extend below the angle of approach or departure or ground clearance limits if it is designed to swing clear. All other steps shall be rigidly constructed. All steps shall have a nonskid surface. The lowermost step(s) shall be no more than 22 in. (558.8 mm) above level ground when the vehicle is fully loaded. Adequate lighting shall be provided to illuminate steps and walkways.

3-12.7

A heavy-duty front bumper shall be mounted on the vehicle and secured to the frame structure.

3-12.8

Attachments shall be provided for all tools, equipment, and other items that the purchaser specifies to be furnished on the vehicle. Equipment holders shall be attached firmly and designed so that equipment remains in place under all operating conditions, but the equipment shall be quickly removable for use.

3-13 Fire-Fighting Systems and Agents.

3-13.1 General.

3-13.1.1 For aircraft rescue and fire-fighting purposes, primary and auxiliary extinguishing agents shall be tested in accordance with NFPA 403, *Standard for Aircraft Rescue and Fire Fighting Services at Airports*.

3-13.1.2 Vehicles designed to discharge auxiliary agents shall require the use of auxiliary agents that are compatible with the primary agent.

3-13.1.3 All components of the agent systems, including such items as the tanks, piping, fill troughs, and screens, shall be made of materials resistant to corrosion by the primary agent, primary agent/water solution, water, and, where specified, the auxiliary agent.

3-13.2 Pump(s) and Pump Drive.

3-13.2.1 Water Pump(s).

3-13.2.1.1 The water pump(s) shall be constructed of corrosion-resistant metals and shall be of the single-stage or multiple-stage centrifugal type and shall be designed for dependable emergency service. It shall be designed carefully and built in accordance with good modern practice. Pumps shall be gravity primed from the vehicle tank. The pump and piping system shall be designed to eliminate the entrapment of air.

3-13.2.1.2 Where discharging foam solution, the pump shall be capable of discharging at a rate equal to or exceeding the total requirements of turrets and hand line nozzles discharging simultaneously at designed pressures.

3-13.2.2 Pump Drive.

3-13.2.2.1 The pump(s) drive shall allow operation of the pump(s) and simultaneous operation of the vehicle. The pump(s) shall not be affected by changes in transmission ratios or the actuation of clutches in the vehicle drive. The design of the drive system and controls shall prevent damage to the drive or minimize lurching of the vehicle when the vehicle drive is engaged during pumping operations. The pump(s) drive system shall be capable of absorbing the maximum torque delivered by the engine to the pump(s) and withstanding the engagement of the pump(s) at all engine speeds and under all operating conditions. The operation of the pump(s) shall not, under any conditions, cause the engine to stall or cause more than a slight and momentary reduction in engine speed and consequent drop in pump pressure.

3-13.2.2.2 While pumping at rated capacity, the drive shall allow controlled vehicle operation at speeds from 1 mph to 5 mph (1.6 km/h to 8 km/h). The pump(s) drive shall have sufficient power capacity to provide the pump discharge requirements of 3-13.2.1.2 while the vehicle is being propelled under all operating conditions where a fire-fighting capability is needed.

3-13.2.2.3 If an independent engine is used to drive the pump(s), it shall have the same fuel and electrical system as the chassis engine and shall be equipped with an air cleaner, replaceable element oil filter, a full pressure lubricating system, and an overspeed governing device to prevent engine damage. The engine also shall be provided with a cooling system that meets the requirements of 3-3.2.1 or 3-3.2.2.

3-13.2.3 Suction Connections. The suction system shall be designed for efficient flow at the pumping rates required by 3-13.2.1.2. The pump suction line(s) shall be of large diameter and of the shortest length consistent with the most suitable pump location. There shall be a drain at the lowest point with a valve for draining all of the liquid from the pumping system where desired. Suction lines and valves shall be constructed of corrosion-resistant materials.

3-13.2.4 Discharge Connections. All discharge outlets shall have National (American) Standard fire hose coupling thread. Adapter couplings, securely attached, shall be provided on each outlet if local couplings are not National (American) Standard as specified in NFPA 1963, *Standard for Fire Hose Connections*.

3-13.2.5 Piping, Couplings, and Valves.

3-13.2.5.1 All piping, couplings, and valves shall be sized for necessary flow with minimum restriction and pressure loss. Material for all piping, couplings, and valves shall be selected to avoid corrosive and galvanic action.

3-13.2.5.2 Piping shall be mounted securely and provided with flexible couplings to minimize stress. Union or rubber-gasketed fittings shall be provided where necessary to facilitate removal of piping.

3-13.2.5.3 All valves shall be of the quarter-turn type and shall be selected for ease of operation and freedom from leakage.

3-13.2.5.4 All water system piping shall be tested on the suction side of the pump to detect possible leakage. All water and foam solution discharge piping, together with the agent pump(s), shall be tested at 50 percent above the system operating pressure.

3-13.2.6 Overheat Protection. A system line shall be provided from the water pump discharge and, if applicable, from the foam pump discharge to prevent overheating of the pumps while engaged and operating at zero (0) discharge. The line shall be automatic.

3-13.2.7 Pressure Relief Valves. A pressure relief valve shall be fitted both to protect and ensure optimum performance of the system.

3-13.3 Water Tank for Nonpressurized Systems.

3-13.3.1 Capacity.

3-13.3.1.1 A water tank shall have a usable capacity as specified in 3-1.2.

3-13.3.1.2 The rated capacity of the tank shall be equal to the usable capacity that can be pumped from the tank while the vehicle is parked on level ground. The tank outlets shall be arranged to allow use of at least 85 percent of the rated capacity with the vehicle positioned as follows:

(a) On a 20-percent side slope;

(b) On a 30-percent ascending grade;

(c) On a 30-percent descending grade.

3-13.3.2 Construction.

3-13.3.2.1 The tank shall be constructed to resist all forms of deterioration that could be caused by the water and foam concentrate while affording the structural integrity necessary for off-road operation. The tank shall have longitudinal and transverse baffles. The construction and connections shall be made to prevent the possibility of galvanic corrosion of dissimilar metals.

3-13.3.2.2 The tank shall be equipped with easily removable manhole covers over the tank discharge. Where specified, the tank shall be designed to allow access within each baffled compartment of the tank for internal and external inspection and service. The tank shall have a drain valve(s).

3-13.3.2.3 Provisions shall be made for necessary overflow and venting. Venting shall be sized to allow agent discharge at the maximum design flow rate without danger of tank collapse and shall be sized to allow rapid and complete filling without exceeding the internal pressure design limit of the tank. Additionally, overflows shall be designed to prevent the loss of water from the tank during normal maneuvering and to direct the discharge of overflow water directly to the ground.

3-13.3.2.4 The water tank shall be mounted in a manner that limits the transfer of the torsional strains from the chassis frame to the tank during off-pavement driving. The tank shall be separate and distinct from the crew compartment, engine compartment, and chassis and shall be easily removable as a unit.

3-13.3.2.5 The water tank shall be equipped with at least one top fill opening of not less than 5 in. (127 mm) internal diameter. The top fill shall be equipped with an easily removable strainer of $^1/_4$-in. (6.4-mm) mesh construction. The top fill opening shall be equipped with a cap designed to prevent spillage.

3-13.3.3 Tank Fill Connection(s).

3-13.3.3.1 A tank fill connection(s) shall be provided in a position where it can be reached easily from the ground.

3-13.3.3.2 All connections shall have National (American) Standard fire hose coupling threads. Securely attached adapters shall be provided on each connection if local couplings are not National (American) Standard. Connections and adapter threads shall be as specified in NFPA 1963, *Standard for Fire Hose Connections*. Connections and connections with adapters attached shall not protrude beyond the normal body metalwork of the vehicle.

3-13.3.3.3 The connection(s) shall be provided with strainers of $^1/_4$-in. (6.4-mm) mesh and shall have check valves or shall be constructed so that water is not lost from the tank when connection or disconnection is made.

3-13.3.3.4 The tank fill connection(s) shall be sized to allow filling of the water tank in 2 minutes at a pressure of 80 psi (551.6 kPa) at the tank intake connection.

3-13.4 Foam Proportioning System.

3-13.4.1 Foam-Liquid Concentrate Tank(s).

3-13.4.1.1 The purchaser shall specify the percent concentrate foam system to be provided. The foam-liquid concentrate tank(s) shall have a working capacity sufficient for two tanks of water at the maximum tolerance specified in NFPA 412, *Standard for Evaluating Aircraft Rescue and Fire Fighting Foam Equipment*.

3-13.4.1.2 Foam-liquid concentrate tanks shall be permitted to be of either the rigid or flexible type. The tank(s) shall be designed for compatibility with the foam concentrate being used and shall resist all forms of deterioration that could be caused by the foam concentrate or water.

3-13.4.1.3 Tanks shall be designed to provide ready access for internal and external inspection and service. A large capacity drain connection shall be installed flush with the bottom of the sump.

3-13.4.1.4 The tank outlets shall be located above the bottom of the sump and shall provide continuous foam-liquid concentrate to the foam proportioning system, with that system operating as specified in 3-13.4.3 and with the vehicle discharging two tank loads of usable water as specified in 3-13.3.1.

3-13.4.1.5 If separate from the water tank, the foam-liquid tank shall be mounted in a manner that limits the transfer of the torsional strains from the chassis frame to the tank during off-pavement driving. The tank shall be separate and distinct from the crew compartment, engine compartment, and chassis and shall be easily removable as a unit.

A flexible tank shall be structurally supported to resist tearing. The structural support shall not be dependent on the fluid level in either the water or foam tanks.

3-13.4.1.6 A top fill trough shall be provided and shall be equipped with a stainless steel No. 10 mesh screen and container openers to allow emptying 5-gal (18.9-L) foam-liquid concentrate containers into the storage tank(s) at a rapid rate regardless of water tank level. The trough shall be connected to the foam-liquid storage tank(s) with a fill line designed to introduce foam-liquid concentrate near the bottom of the tank(s) to minimize foaming within the storage tank.

3-13.4.1.7 The tank fill connection(s) shall be provided in a position where it can be reached easily from the ground to allow the pumping of foam-liquid concentrate into the storage tank(s). The connection(s) shall be provided with strainers of $^{1}/_{4}$-in. (6.4-mm) mesh and shall have check valves or be constructed so that foam is not lost from the tank when connection or disconnection is made.

Where flexible tanks are used, the supply system shall be designed so that the flexible tanks are not subject to excess pressure. The supply system shall be capable of delivering foam-liquid at a rate at least equal to or greater than the maximum discharge rate of the foam system.

3-13.4.1.8 The tank(s) shall be vented adequately to allow rapid and complete filling without the buildup of excessive pressure and to allow emptying the tank at the maximum design flow rate without danger of collapse. The vent outlets shall be directed to the ground to prevent spillage of foam-liquid concentrate on vehicle components.

3-13.4.2 Foam-Liquid Concentrate Piping.

3-13.4.2.1* The foam-liquid concentrate piping shall be of material resistant to corrosion by foam-liquid concentrate. Care shall be taken that combinations of dissimilar metals that produce galvanic corrosion are not selected or that such dissimilar metals are electrically insulated. Where plastic piping is used, it shall be fabricated from unplasticized resins, unless it has been demonstrated that the stipulated plasticizer does not adversely affect the performance characteristics of the foam-liquid concentrate. The plastic pipe shall be permitted to be reinforced with glass fibers.

3-13.4.2.2 The foam-liquid concentrate piping shall be adequately sized to allow the maximum required flow rate and shall be arranged to prevent water from entering the foam tank.

3-13.4.3 Foam-Liquid Proportioning System.

3-13.4.3.1 The foam concentrate proportioning system shall provide a means of controlling the ratio of foam concentrate to the quantity of water in the foam solution being discharged from all orifices normally used for aircraft fire-fighting operations.

3-13.4.3.2 The proportioning system shall be sufficiently accurate to provide for the discharge of finished foam within the range specified in NFPA 412, *Standard for Evaluating Aircraft Rescue and Fire Fighting Foam*.

3-13.5 Premixed — Pump System.

Where premix solution in the main water tank is selected as the means of proportioning foam to water, the foam solution used shall be AFFF only. Care shall be exercised that the premixed solution is mixed to exact proportions. Where premix solution is used, operation of the vehicle fire-fighting system shall conform to the requirements of 3-13.2 and 3-13.3.

3-13.6 Premixed — Pressurized System.

3-13.6.1 Liquid Agent Container(s).

3-13.6.1.1 The storage container(s) and liquid agent(s) shall be designed for pressurization and shall be constructed in accordance with the ASME *Boiler and Pressure Vessel Code* and shall be so marked.

3-13.6.1.2 The material of construction shall be resistant to corrosion by the AFFF agent to be stored, or a suitable lining material shall be provided.

3-13.6.1.3 An ASME-approved pressure relief valve of adequate capacity shall be provided on the container and set to prevent pressures in excess of the maximum design working pressure. A pressure gauge shall be provided that indicates the internal pressure of the agent storage container at all times.

3-13.6.1.4 A readily accessible fill opening of sufficient size to allow ease in filling, and stirring if necessary, shall be provided. It shall be in compliance with ASME or local codes and in no case shall be less than 3 in. (76.2 mm) in diameter. Filling shall be accomplished without the removal of any of the extinguisher piping or any major component.

3-13.6.1.5 A means shall be provided to determine the contents of the container as a guide in recharging partial loads.

3-13.6.2 Propellant Gas.

3-13.6.2.1 The propellant gas shall be dry nitrogen or dry compressed air and provided in sufficient quantity to expel the fire-fighting agent as well as to purge all piping and hose lines after use.

3-13.6.2.2 All propellant gas cylinders and valves shall be in accordance with U.S. Department of Transportation (DOT) requirements or regulations. Cylinders shall bear the DOT marking.

3-13.6.2.3 The design of the propellant source shall provide for quick and easy replacement after each use.

3-13.6.2.4 A pressure gauge shall be provided and shall indicate the pressure of the propellant gas source at all times.

3-13.6.2.5 Cylinder valves, gauges, and piping shall be arranged to preclude accidental mechanical damage.

3-13.6.2.6 The cylinder valve shall be capable of being opened by quick-acting control and also shall be suitable for remote operation.

3-13.6.3 Pressure Regulation.

3-13.6.3.1 Pressure regulation shall be designed to reducethe normal cylinder pressure automatically and to hold the propellant gas pressure at the designed operating pressure of the liquid agent container(s).

3-13.6.3.2 All pressure regulating devices shall be sealed or pinned at the designed operating pressures after final adjustment by the system manufacturer.

3-13.6.3.3 Pressure regulating devices shall be equipped with a spring-loaded relief valve that relieves any excess pressure that develops in the regulator.

3-13.6.3.4 The pressure regulator shall be permitted to be of a type without pressure indicating gauges.

3-13.6.4 Piping and Valves.

3-13.6.4.1 All propellant piping and fittings shall conform to the appropriate ASME code and shall be designed to withstand the working pressure of the system. The design of the piping and valving shall provide the desired flow of gas into the system and the minimum amount of restriction from the liquid agent container(s) to the hose connection. Where more than one hose line is provided, piping and fittings shall be sized and designed so that there is equal flow to each line, regardless of the number of lines placed in operation.

3-13.6.4.2 Provisions shall be made for purging all piping and hose of the liquid after use without discharging the liquid agent remaining in the container(s). Provisions also shall be made for the depressurization of the liquid agent container(s) without the loss of the remainder of the liquid agent.

3-13.6.4.3 Drains shall be provided to allow complete draining of the system.

3-13.6.4.4 All valves shall be of the quarter-turn, quick-opening, ball type. A maximum of two operations, exclusive of the nozzle, shall be provided to charge the system. Controls shall be arranged for simultaneous charging of the liquid agent and dry chemical systems.

Exception: Valves on the gas cylinder specified in 3-13.6.2.2 shall not be required to be of the quarter-turn, quick-opening ball type.

3-13.6.4.5 A quick-acting control to be operated by the driver to pressurize the liquid agent system from the cab of the vehicle shall be provided, with a similar control at the unit.

3-13.6.4.6 All valves and piping shall be resistant to corrosion by the foam-liquid concentrate.

3-13.6.4.7 A check valve shall be provided in the gas piping to prevent the liquid agent from being forced back into the propellant gas line.

3-13.7 Dry Chemical System.

3-13.7.1 General.

3-13.7.1.1 The dry chemical container(s) shall be constructed in accordance with the ASME *Boiler and Pressure Vessel Code*, Section 8, and shall be so stamped.

3-13.7.1.2 All piping and fittings shall conform to the appropriate ASME code and shall be designed to withstand the working pressure of the system. The design of the piping and valving shall provide the desired flow of gas into the system and the minimum amount of restriction from the chemical container(s) to the hose connection. Where more than one hose line is provided, piping and fittings shall be sized and designed so that there is equal flow to each line, regardless of the number of lines placed in operation.

3-13.7.1.3 Provisions shall be made for purging all piping and hose of dry chemical after use without discharging the dry chemical remaining in the dry chemical container(s). Provisions also shall be made for the depressurization of the dry chemical container(s) without the loss of the remainder of the dry chemical. A pressure gauge shall be provided that indicates the internal pressure of the agent storage container(s) at all times.

3-13.7.1.4 The system shall be designed to ensure fluidization of the dry chemical at the time of operation. Where any design includes the movement of the chemical container(s) to fluidize the contents, such design also shall include a manual operating feature.

3-13.7.1.5 A check valve shall be provided in the gas piping to prevent the extinguishing agent from being forced back into the propellant gas line.

3-13.7.1.6 A means of pressure relief conforming to appropriate ASME codes shall be provided for the dry chemical container(s) and piping to prevent overpressurization in the event of a malfunction in the propellant gas regulator system or in the event the container is involved in a severe fire exposure.

3-13.7.1.7 The fill opening in the dry chemical container shall be located so that it is easily accessible for recharging and necessitates a minimum amount of time and effort to open and close. Filling shall be accomplished without the removal of any of the extinguisher piping or any major component.

3-13.7.1.8 A quick-acting control to be operated by the driver to pressurize the dry chemical agent system from the cab of the vehicle shall be provided, with a similar control at the hand line.

3-13.7.2 Propellants.

3-13.7.2.1 The propelling agent shall be dry nitrogen or dry air.

3-13.7.2.2 All propellant gas cylinders and valves shall be in accordance with U.S. Department of Transportation (DOT) requirements or regulations. Cylinders shall bear the DOT marking.

3-13.7.2.3 The method of adequately pressurizing and propelling the dry chemical in the system shall provide a sufficient quantity of gas to expel the agent, as well as allowing the complete purging of all piping and hose lines after each use.

3-13.7.2.4 The design of the propellant source shall provide for quick and easy replacement after each use.

3-13.7.2.5 A pressure gauge shall be provided and shall indicate the pressure on the propellant gas source at all times.

3-13.7.2.6 Cylinder valves, gauges, and piping shall be arranged to preclude accidental mechanical damage.

3-13.7.3 Pressure Regulation.

3-13.7.3.1 Pressure regulation shall be designed to reduce the normal cylinder pressure automatically and to hold the propellant gas pressure at the designed operating pressure of the dry chemical container(s).

3-13.7.3.2 All pressure regulating devices shall be sealed or pinned at the designed operating pressures after final adjustment by the system manufacturer.

3-13.7.3.3 Pressure regulating devices shall be equipped with a spring-loaded relief valve that relieves any excess pressure that develops in the regulator.

3-13.7.3.4 The pressure regulator shall be permitted to be of a type without pressure indicating gauges.

3-13.8 Halon 1211 System.

3-13.8.1 Halon Container.

3-13.8.1.1 The storage container shall be designed for pressurization and shall be constructed in accordance with the ASME *Boiler and Pressure Vessel Code* and shall be so marked.

3-13.8.1.2 The material of construction shall be resistant to corrosion by the halon agent to be stored.

3-13.8.1.3 A readily accessible charge coupling of sufficient size to allow ease in filling shall be provided. Filling shall be accomplished without the removal of any of the extinguisher piping or any major component. A pressure gauge shall be provided that indicates the internal pressure of the agent storage container at all times.

3-13.8.1.4 A means shall be provided to determine the contents of the container as a guide in recharging partial loads and to prevent overfilling of the tank.

3-13.8.2 Propellant Gas.

3-13.8.2.1 The propellant gas shall be dry nitrogen or dry compressed air and provided in sufficient quantity to expel the halon agent as well as purge all piping and hose lines after use.

3-13.8.2.2 All propellant gas cylinders and valves shall be in accordance with U.S. Department of Transportation (DOT) requirements or regulations. Cylinders shall bear the DOT marking.

3-13.8.2.3 Pipes and valves connected to the halon container shall conform to the appropriate ASME code and shall be designed to withstand the working pressure of the system.

3-13.8.2.4 The design of the propellant source shall provide for quick and easy replacement after each use.

3-13.8.2.5 A pressure gauge shall be provided and shall indicate the pressure of the propellant gas source at all times.

3-13.8.2.6 Cylinder valves, gauges, and piping shall be arranged to preclude accidental mechanical damage.

3-13.8.2.7 A check valve shall be provided in the gas piping to prevent the liquid agent from being forced back into the propellant gas line.

3-13.8.3 Pressure Regulation.

3-13.8.3.1 An ASME-approved pressure relief valve of adequate capacity shall be provided on the container and shall be set to prevent pressures in excess of the maximum design working pressure.

3-13.8.3.2 Pressure regulation shall be designed to reduce the normal cylinder pressure automatically and to hold the propellant gas pressure at the designed operating pressure of the halon container.

3-13.8.3.3 All pressure regulating devices shall be sealed or pinned at the designed operating pressures after final adjustment by the system manufacturer.

3-13.8.3.4 Pressure regulating devices shall be equipped with a spring-loaded relief valve that relieves any excess pressure that develops in the regulator.

3-13.8.3.5 The pressure regulator shall be permitted to be of a type without pressure indicating gauges.

3-13.8.4 Halon Delivery Piping and Valves.

3-13.8.4.1 All piping, couplings, and valves shall be sized for necessary flow with minimum restriction and pressure loss. Material for all piping, couplings, and valves shall be selected to avoid corrosive and galvanic action. Piping shall be mounted securely and provided with flexible couplings to minimize stress.

3-13.8.4.2 All valves shall be of the quarter-turn type and shall be selected for ease of operation and freedom from leakage.

3-13.8.4.3 All discharge piping shall be tested at 50 percent above the system operating pressure.

3-13.8.4.4 Where more than one hose line is provided, piping and fittings shall be sized and designed so that there is equal flow to each line, regardless of the number of lines placed in operation.

3-13.8.4.5 Provisions shall be made for purging all piping and hose of the halon after use without discharging the halon remaining in the container(s). Provisions also shall be made for venting of the halon container without loss of the remainder of the liquid agent.

3-13.8.4.6 A quick-acting control to be operated by the driver to pressurize the halon system from the cab of the vehicle shall be provided, with a similar control at the hand line.

3-13.9 Primary Turret Nozzles.

3-13.9.1 Classes 2, 3, and 4 vehicles shall have a foam turret or a twin (dry chemical and foam) turret. Where Halon 1211 is utilized, a twin turret shall not be required.

3-13.9.2 The nominal foam solution discharge rate from the foam turret shall be 150 gpm (567.8 lpm) for Class 2 vehicles, 200 gpm (757 lpm) for Class 3 vehicles, and 250 gpm (946.3 lpm) for Class 4 vehicles. The roof turret discharge rate shall have a tolerance of +10 percent/-0 percent.

3-13.9.3 Both single foam turrets and the foam barrel of a twin turret for simultaneous agent discharge shall be capable of discharging foam, as specified in Table 3-13.9.3, in still air in a variable pattern with the turret elevated to the maximum stream reach position.

Table 3-13.9.3 Foam Turret Barrel Pattern

Vehicle Class	Straight Stream	Dispersed Stream	
	Far Point (ft) (m)	Full Width (ft) (m)	Full Width Far point (ft) (m)
2	125 38	20 6	25 7.6
3	125 38	25 7.6	25 7.6
4	125 38	25 7.6	25 7.6

3-13.9.4 The dry chemical barrel of a twin turret for simultaneous agent discharge shall be designed to dispense the dry chemical agent at a minimum discharge rate of ≥ 16 lb/sec to ≤ 22 lb/sec (≥ 7.3 kg/sec to ≤ 10.0 kg/sec) and with a minimum far point range of not less than 100 ft (30.5 m), with a pattern width not less than 17 ft (5.2 m) with the turret stationary.

3-13.9.5 The foam barrel of a twin turret for simultaneous agent discharge shall be positioned so that the foam stream pattern falls to the ground 10 ft (3 m) behind the dry chemical stream pattern.

3-13.9.6 Turret controls for both foam and dry chemical turrets shall be accessible both to the driver and the crew member.

3-13.9.7 Both single and twin turrets shall be capable of being elevated at least 45 degrees above the horizontal and depressed to discharge agent within 20 ft (6.1 m) in front of the vehicle at full output using a dispersed stream. The turret shall be capable of being rotated not less than 90 degrees to either side, with total traverse not less than 180 degrees. Where two turrets are used on a vehicle, suitable stops shall be provided so that neither turret can interfere with the other turret.

3-13.9.8 The dry chemical agent system shall be designed so that the operator can discharge both the primary and the auxiliary agent system separately or simultaneously.

3-13.10 Preconnected Hand Lines, Reels, and Nozzles.

3-13.10.1 Combined agent vehicles shall have at least one preconnected hand line and nozzle for each agent. Hand lines and nozzles shall be permitted to be separate or twinned together for simultaneous agent discharge. Hand lines shall be permitted to be reeled hand lines as specified in 3-13.10.2 or woven jacket hand lines as specified in 3-13.10.3.

3-13.10.2 Preconnected Hand Lines.

3-13.10.2.1 Preconnected hand lines for reels shall have a minimum internal diameter of 1 in. (25.4 mm), shall have a minimum burst pressure rating three times the nominal working pressure of the system, and shall discharge the gpm (lpm) required in 3-13.10.2.3 without unreeling the hose.

3-13.10.2.2 At least 100 ft (30.5 m) of hose shall be provided for each reel.

3-13.10.2.3 Each hand line shall be equipped with a shutoff-type nozzle designed to discharge both foam and water at a nominal discharge rate of 60 gpm (227.1 lpm), +10 percent/–0 percent. Each nozzle shall have minimum foam discharge patterns from a dispersed stream of 15 ft (4.6 m) in width and 20 ft (6.1 m) in range to a straight foam stream with a 50-ft (15.2-m) range.

3-13.10.2.4 Each reel shall have capacity for at least 100 ft (30.5 m) of 1-in. (25.4-mm) hose or more if specified by the purchaser.

3-13.10.2.5 Each reel shall be designed and positioned to allow hose line removal by a single person from any position in a 120-degree horizontal sector. Each reel shall be equipped with a friction brake to prevent the hose from unreeling when not desired. A power rewind with manual override shall be provided. The nozzle holder, friction brake, rewind controls, and manual valve control shall be accessible from the ground.

3-13.10.2.6 The discharge control to each hand line shall be adjacent to the hand line and accessible to the person using the hand line.

3-13.10.3 Woven Jacket Hand Lines.

3-13.10.3.1 Woven jacket hand lines shall have a minimum diameter of $1^1/_2$ in. (38.1 mm) and shall meet the requirements of NFPA 1961, *Standard for Fire Hose*.

3-13.10.3.2 At least 150 ft (45.7 m) of hose shall be provided for each hand line.

3-13.10.3.3 Each hand line shall be equipped with a shutoff-type nozzle designed to discharge both foam and water at a nominal discharge rate of 95 gpm (359.6 lpm), +10 percent/–0 percent.

Each nozzle shall have minimum foam discharge patterns from a dispersed stream of 15 ft (4.6 m) in width and 20 ft (6.1 m) in range to a straight foam stream with a 65-ft (19.8-m) range.

3-13.10.3.4 Each hand line shall be stored, flat loaded, in a hose compartment and shall be preconnected. Each hose compartment shall have a capacity for a minimum of 150 ft (45.7 m) of $1^{1}/_{2}$-in. (38.1-mm) multiple jacket hose or more if specified by the purchaser.

3-13.10.3.5 Hose compartments shall be fabricated from noncorrosive material and shall be designed to drain effectively. The compartment shall be smooth and free from all projections that might damage the hose. No other equipment shall be mounted or located where it can obstruct the removal of the hose. Each preconnected hand line compartment shall be located so that the distance between the hand line nozzle and the ground, step, or deck plate upon which the operator stands to initiate the pulling of the hand line from the reel or the top lay of the woven jacket hose is not more than 6 ft (1.8 m) above that surface.

3-13.10.3.6 The discharge control to each hand line shall be adjacent to the hand line and accessible to the person using the hand line.

3-13.10.4 Auxiliary Agent Hand Lines.

3-13.10.4.1 Hand lines for auxiliary agents shall have a minimum burst pressure rating three times the nominal working pressure of the system and meet the requirements specified below. The auxiliary agent hand line shall be equipped with a nozzle that allows a fully opened to a fully closed position in a single, simple movement and shall be designed to discharge agent at a minimum rate of ≥5 lb/sec to ≤7 lb/sec (≥2.3 kg/sec to ≤3.3 kg/sec) at a minimum range of 20 ft (6.1 m). Nozzle construction shall be of nonferrous metal or stainless steel.

3-13.10.4.2 Twinned hand lines and nozzles shall be designed so that each agent can be discharged separately or simultaneously. The barrels shall be linked together to provide coordinated application by one operator.

3-13.10.4.2.1 Each reel shall have capacity for at least 100 ft (30.5 m) of 1-in. (25.4-mm) hose or more if specified by the purchaser.

3-13.10.4.2.2 Each reel shall be designed and positioned to allow hose line removal by a single person from any position in a 120-degree horizontal sector. Each reel shall be equipped with a friction brake to prevent the hose from unreeling when not desired. A power rewind with manual override shall be provided. The nozzle holder, friction brake, rewind controls, and manual valve control shall be accessible from the ground.

3-13.10.4.2.3 The discharge control to each hand line shall be adjacent to the hand line and accessible to the person using the hand line.

3-13.11 Foam Quality.

Turrets and hand lines shall discharge foam having the quality specified in NFPA 412, *Standard for Evaluating Aircraft Rescue and Fire Fighting Foam Equipment*.

Measurement of the expansion ratio and 25-percent drainage times shall be in accordance with the procedures outlined in NFPA 412.

3-14 Lighting and Electrical Equipment.

3-14.1

Lighting equipment shall be installed in conformity with local road regulations, where practicable, and shall include the following:

(a) Headlights with upper and lower driving beams. A control switch that is readily accessible to the driver shall be provided for beam selection.

(b) Dual taillights and stoplights.

(c) Self-canceling turn signals, front and rear, with a steering column-mounted control and a visual and audible indicator. A four-way flasher switch shall be provided.

(d) Where specified, a minimum 6-in. (152.4-mm) spotlight on both left and right sides of the windshield, hand-adjustable type, with controls for beam adjustments inside the truck cab.

(e) Adequate reflectors, and marker and clearance light, shall be furnished to describe the overall length and width of the vehicle.

(f) Engine compartment lights, nonglare type, arranged to illuminate both sides of the engine, with individual switches located in the engine compartment. Service lighting shall be provided for all areas described in 2-12.2(a), (b), and (c), as well as for the engine compartment.

(g) Two swivel-mounted lights, 6 in. (152.4 mm) minimum, with clear lens and individual switches, mounted on the top deck for equipment lighting.

(h) Lighting provided for all top deck working areas.

(i) At least one back-up light and an audible alarm with a minimum of 97 dBA meeting SAE J994, *Standard on Alarm-Backup-Electric Laboratory Performance Testing*, installed in the rear of the body.

(j) A flashing red beacon or alternate red and white flashing lights mounted on the top deck and visible for 360 degrees in the horizontal plane. The mounting of the beacon also shall provide good visibility from the air. A control switch shall be provided on the instrument panel in the cab for control of the beacon.

3-14.2*

A warning system shall be provided that has a sound output of not less than 95 dBA at 100 ft (30.5 m), when measured directly ahead of the siren and not less than 90 dBA at 100 ft (30.5 m), measured at 45 degrees on either side. The siren shall be mounted to allow maximum forward sound projection but shall be protected from foam dripping from the turret or water splashed up by the tires.

3-14.3

A master switch for all emergency lights shall be provided.

3-14.4

An electric or air horn shall be provided and shall be mounted at the front part of the vehicle with the control positioned so that it is readily accessible to the driver.

3-14.5

Where furnished, air horns, an electric siren(s), and an electronic siren speaker(s) shall be mounted as low and as far forward on the apparatus as practical. Audible warning equipment shall not be mounted on the roof of the apparatus.

3-14.6 Radios.

3-14.6.1 Provision shall be made for mounting radios. Operation of the radios shall be from the cab. Radios shall be mounted to allow quick servicing or replacement.

3-14.6.2 The purchaser shall specify all necessary radios and frequencies that are to be provided.

3-15* Tools.

Provision shall be made for mounting tools and equipment, as specified by the purchaser, on the truck. Special tools for servicing the vehicle, fire suppression system, and any of the auxiliary equipment shall be furnished as necessary by the vehicle manufacturer.

Chapter 4 Acceptance Criteria

4-1 General.

4-1.1

Compliance with the requirements of this standard shall be verified by one of the following methods:

(a) The component manufacturer's certification;

(b) Prototype vehicle tests;

(c) Operational tests.

4-1.2

The component manufacturer's certification shall be provided where specified in Section 4-2. The manufacturer shall certify that the component is approved for use in the RFF application.

4-1.3

Prototype vehicle tests shall be conducted by the manufacturer in accordance with the standardized procedures found in Section 4-3 to ensure that the performance requirements have been achieved with the design. Calculated performance capability shall not be substituted for an actual prototype test.

4-1.4

Operational tests shall be performed either at the airport or the manufacturer's facility as specified in Section 4-4. The test shall be conducted by the manufacturer on every vehicle built.

4-1.5

The manufacturer of the vehicle shall demonstrate to the purchasing authority or its designee the care and maintenance and operational capability of the vehicle.

4-2 Component Manufacturer's Certification.

4-2.1

A copy of the manufacturer's signed application for approval shall be provided with the vehicle documents for the following components:

(a) Engine;

(b) Transmission;

(c) Axles;

(d) Transfer case;

(e) Wheels;

(f) Tires;

(g) Hand line hose with couplings attached;

(h) Premixed storage container;

(i) Premixed system pressure relief valve;

(j) Propellant gas cylinder;

(k) Propellant gas cylinder regulating device;

(l) Complementary agent storage container;

(m) Complementary agent pressure relief device.

4-2.2

The cooling system shall be certified by the vehicle manufacturer to satisfy all operational conditions at all ambient temperatures encountered at the operational airport for both the engine and the transmission.

4-2.3

The brake system shall be certified by the vehicle manufacturer to satisfy the service brake, emergency brake, and grade-holding performance requirements for the corresponding class of vehicle.

4-2.4

Where the vehicle is equipped with an air brake system, the vehicle manufacturer shall provide itemized, certified data relative to the air system as follows:

(a) Total reservoir capacity;

(b) Total required volume (twelve times the total combined brake chamber volume at full stoke);

(c) Quick buildup system capacity;

(d) Quick buildup system pressure needed to release the spring brakes.

4-3 Prototype Vehicle Tests.

Where the vehicle is fitted with an extendable turret (*see definition in Section 1-3*), the test shall be conducted with the extendable turret in the stowed position.

4-3.1 Rated Water/Foam Tank Capacity Test.

4-3.1.1 Test facilities shall consist of an open site suitable for discharging agent that includes both level ground and measured grades of at least 20 percent and 30 percent. Access to a refill water supply shall be required.

4-3.1.2 Test equipment shall consist of the following:

(a) A calibrated sight gauge;

(b) A liquid volume measuring device accurate to within ± 1.0 percent;

(c) *Alternative:* A stopwatch and a scale capable of measuring the total vehicle weight accurate to within ± 1.0 percent.

4-3.1.3 The vehicle shall have had its primary turret(s) discharge rate verified prior to beginning this test to ensure that the turret(s) discharges at or above the minimum rate specified, and the accuracy of the foam metering system shall have been verified.

4-3.1.4 The rated water and foam tank capacity shall be determined as follows:

(a) Park the vehicle on level ground.

(b) If necessary, attach a calibrated site gauge to both the water tank and the foam tank.

(c) Fill the water piping up to a level even with the bottom of the tank. Do not record the water quantity used.

(d) *Alternative:* After completion of 4-3.1.4(c), record the weight of the vehicle. Fill the water tank and foam tank and record the weight of the vehicle.

(e) While filling both tanks with a liquid volume measuring device, correlate and record the amount of water added to each tank with the site gauge calibrations. When the tanks are filled to the top, record the total liquid capacity for each tank.

(f) Add dye to the foam tank.

(g) Set the agent system to discharge at the specified foam solution rate, and adjust the system discharge pressure to the recommended pressure.

(h) Starting with tanks that are completely full, discharge at maximum rate through the primary turret(s) until the agent pump(s) shows a drop in discharge pressure, and then stop immediately. Verify that dye is apparent in the discharge stream throughout the test. Record the discharge time if using the weight measurement method.

(i) *Alternative:* Record the weight of the vehicle after discharging. Calculate the pump-out capacity of the water tank using the weight of the water plus the foam discharged, the foam proportioning rate as verified in 4-3.1.3, and the discharge time.

(j) Measure the amount of liquid remaining in both tanks and convert to gallons using the conversion established in 4-3.1.4(e). Subtract the amount remaining from the total capacity to determine the amount pumped out. Record the total amount of liquid pumped out of the tanks.

(k) Refill the water tank only (not the foam tank). Discharge the water tank as in 4-3.1.4(h). Verify that dye is apparent throughout the test. Measure and record the additional amount of liquid discharged from the foam tank. Fill the water tank and discharge as many times as necessary to eliminate all usable liquid from the foam tank.

(l) Total and record the amount of liquid discharged from the foam tank from the time of initial fill.

(m) Refill both tanks and repeat 4-3.1.4(f) through (k) with the vehicle parked in the following attitudes:

After pumping on a slope, with the vehicle in the following slope conditions, return the vehicle to level ground to measure the water volume discharged:

1. A 20-percent side slope, left side up;
2. A 20-percent side slope, right side up;
3. A 30-percent slope, ascending;
4. A 30-percent slope, descending;

(n) Divide the volume of liquid discharged from each tank on the four slope conditions by 0.75 and record.

4-3.1.5 The rated or usable water tank capacity shall be the lesser of the volumes calculated in 4-3.1.4(j) or 4-3.1.4(n). The rated or usable foam tank capacity shall be the lesser of the volumes calculated in 4-3.1.4(l) or 4-3.1.4(n).

4-3.2 Side Slope.

4-3.2.1 Test facilities shall consist of either a measured fixed grade equal to or in excess of the slope requirement for the class of vehicle being tested or a surface on which the tires of the vehicle can be placed that is capable of being tilted. Means to restrain the vehicle at the balance point shall be required.

4-3.2.2 Test equipment shall consist of a suitable inclinometer capable of measuring the slope of the support surface with an accuracy of ± 1 degree.

4-3.2.3 Vehicle Testing.

4-3.2.3.1 The vehicle shall be tested in its fully loaded condition (*see definition of Fully Loaded Vehicle in Section 1-3*) with tires inflated to their recommended operating pressure. A suitable ballast shall be used in place of the crew for safety.

4-3.2.3.2 Where the vehicle is fitted with an extendable turret, an additional test shall be performed as follows:

Tilt the vehicle on a table, or position the vehicle on a 20-percent grade. Elevate the extendable turret to the highest elevation. Position the turret nozzle uphill at maximum horizontal rotation, and discharge the agent at maximum flow rate for the class of vehicle being tested.

4-3.2.4 The side slope capability of the vehicle shall be determined as follows:

(a) Tilt the vehicle on a table, or position the vehicle on a grade having an angle above the horizon at least equal to the side slope angle specified for the vehicle being tested.

(b) Once the vehicle is positioned at the required angle, check the vehicle restraints to ensure that no tension is applied.

4-3.2.5 The vehicle shall be considered to meet its side slope requirement if the vehicle can stand by itself on the grade without the use of the safety restraints.

4-3.3 Cornering Stability.

4-3.3.1 Test facilities shall consist of a level site having a dry, paved surface at least 250 ft (76.2 m) in diameter that is free from loose material upon which a circle with a radius of 100 ft (30.5 m) shall be marked in a manner that can be followed easily by a driver.

4-3.3.2 A calibrated speedometer and a means of indicating steering wheel angle shall be required.

4-3.3.3 The vehicle shall be tested in its fully loaded condition. (*See definition of Fully Loaded Vehicle in Section 1-3.*)

4-3.3.4 The vehicle shall be tested as follows:

(a) Slowly drive the vehicle around the 100-ft (30.5-m) radius circle while keeping the centerline of the front of the vehicle directly over the marked line.

(b) Establish a reference position on the steering wheel position indicator at a slow speed.

(c) Gradually increase the speed until the maximum safe speed, as judged by the driver, is reached.

(d) Record the maximum speed and the corresponding position of the steering wheel.

(e) Repeat 4-3.3.4(a) through (d) while driving the vehicle in the opposite direction.

4-3.3.5 The speed achieved shall equal or exceed the requirement for the corresponding class of vehicle, and the steering angle shall not decrease with increasing speed.

4-3.4 Vehicle Dimensions.

4-3.4.1 Test facilities shall consist of a flat measurement pad that is large enough to accommodate the entire vehicle.

4-3.4.2 Test equipment shall consist of a tape measure and a protractor.

4-3.4.3 The vehicle shall be tested in its fully loaded condition (*see definition of Fully Loaded Vehicle in Section 1-3*) with tires inflated to their recommended operating pressure.

4-3.4.4 The following vehicle dimensions shall be measured in accordance with their definitions with the vehicle positioned on the flat pad:

(a) Angle of approach;

(b) Angle of departure;

(c) Interaxle clearance angle;

(d) Underbody clearance;

(e) Underaxle clearance.

4-3.4.5 Linear dimensions shall be rounded down to the nearest $^1/_2$ in. (1.3 cm), and angular dimensions shall be rounded down to the nearest $^1/_2$ degree and compared against the vehicle specifications.

4-3.5 Driver Vision Measurement.

4-3.5.1 Test facilities shall consist of a level site at least 20 ft (6.1 m) longer than the vehicle.

4-3.5.2 Test equipment shall consist of a plumb bob, tape measure, and a protractor or an inclinometer.

4-3.5.3 The vehicle shall be tested in its fully loaded condition (*see definition of Fully Loaded Vehicle in Section 1-3*) with tires inflated to their recommended operating pressure.

4-3.5.4 The driver's vision shall be determined as follows:

(a) Adjust the driver's seat to its mid position with respect to height, weight, and fore and aft adjustments.

(b) Place a suitable structure on the seat cushion for locating an eye height of $31^3/_4$ in. (806.5 mm) and a position 12 in. (30.5 cm) forward from the seat back. Place the seat back in a vertical position.

(c) Establish the features that limit the upward and downward line of vision that are located directly in front of the driver's seat.

(d) Measure and record the angle above the horizon at which upward vision is obstructed from the eye height point established in 4-3.5.4(b).

(e) Establish the lowest possible line of vision below the horizon directly in front of the eye height point and project this line forward of the cab until it intersects with the ground. Project this line of vision by using a light beam, or, if the windshield is removed, use a string line. Measure and record the distance from this intersection with the ground and the front face of the bumper at the front of the truck.

(f) Stretch a line from the eye height point laterally across the cab in order to establish and record the 90-degree line of vision to the left and right of the straight ahead position. Note obstructions within these angles.

4-3.5.5 The recorded values for the distance at which the line of vision meets the ground in front of the truck and the angle of vision above the horizon shall equal or exceed the vehicle's specification. Obstacles within the 90-degree horizontal line of vision to the right or left shall not create an obstruction of more than 5 degrees per obstruction.

4-3.6 Pump and Roll on a 40-Percent Grade.

4-3.6.1 Test facilities shall consist of a site suitable for discharging agent that includes a measured grade of 40 percent that is at least twice the vehicle's length or a level, paved test pad adequate for an extended draw bar pull.

4-3.6.2 Test equipment shall consist of the following:

(a) A calibrated speedometer;

(b) A vehicle equipped pump pressure gauge;

(c) A load cell accurate to within ± 500 lb (± 227 kg) (applicable only to the alternate draw bar method);

(d) A variable load dynamometer sled (applicable only to the alternate draw bar method).

4-3.6.3 The vehicle shall have had its primary turret(s) discharge rate and pressure verified prior to beginning this test to ensure that the turret(s) discharges at or above the minimum rate specified. The vehicle shall be tested in its fully loaded condition (*see definition of Fully Loaded*

Vehicle in Section 1-3) with tires inflated to their recommended operating pressure.

4-3.6.4 The capability of the vehicle to ascend, stop, start, and continue ascent on a 40-percent grade without interruption in the discharge rate shall be demonstrated either on an actual grade or by means of an equivalent draw bar test as follows:

(a) Fill both the water and foam tanks with water, and add dye to the foam tank.

(b) Set the agent system to discharge in the foam mode, and set the system discharge pressure for optimum performance.

(c) Position the vehicle at the bottom of a 40-percent grade and initiate discharge at full output through the primary turret nozzles. Verify that dye is apparent in the discharge stream throughout the test.

(d) Initiate the vehicle's ascent of the grade and achieve a speed of at least 1 mph (1.6 km/h). During the ascent, bring the vehicle to a stop and resume the ascent at a speed of at least 1 mph (1.6 km/h) without interruption in the discharge stream. Record the vehicle speed and any variation in discharge pressure.

(e) If an actual 40-percent grade is not available, repeat 4-3.6.4(a) through (d) with the vehicle coupled to a 40-percent grade equivalent draw bar load determined as follows:

1. A 40-percent grade — 21.8-degree angle.

2. The loaded vehicle weight × sin 21.8 degrees (0.371) equals the necessary draw bar pull to simulate ascending a 40-percent grade.

3. The area of the load cell shall be determined at the time of the test.

4. The load cell reading, in psi (kPa), that simulates a 40-percent grade shall be calculated by the following:

$$\frac{\sin 21.8 \text{ degrees} \times \text{vehicle weight}}{\text{area of load cell}}$$

4-3.6.5 The vehicle shall negotiate the grade or draw bar pull smoothly while maintaining an operating pressure of at least 50 percent of the specified design pressure for the primary turret(s) at speeds of at least 1 mph (1.6 km/h).

4-3.7 Electrical Charging System.

4-3.7.1 Test facilities shall consist of an area suitable for running the engine while the electric loads and charging rates are being measured.

4-3.7.2 Test instrumentation shall consist of the following:

(a) A laboratory quality voltmeter with a scale range compatible with the design voltage of the vehicle's electrical system. The scale on the voltmeter shall be graduated to allow reading voltages with a ± 0.1-volt accuracy.

(b) A laboratory quality ammeter with a scale range compatible with the anticipated electrical load present on the vehicle. The ammeter shall be graduated to allow reading current flow within a ± 3-percent accuracy.

(c) The tachometer installed in the vehicle.

4-3.7.3 The test vehicle shall have a fully charged set of batteries, and the vehicle's electric and charging systems shall be fully operational. The test shall be conducted in ambient conditions of 50°F to 90°F (10°C to 32.2°C).

4-3.7.4 The test shall be conducted as follows:

(a) Check each battery cell to verify that voltage and specific gravity are at the battery manufacturer's specifications.

(b) Install a voltmeter to monitor the battery charge continuously during the test.

(c) Install an ammeter/shunt system at the battery to measure the full current demand of the electrical system. Install another ammeter/shunt system at the alternator to measure the total current output of the alternator.

(d) Record voltage and ampere readings under the following conditions:

1. Battery (engine off, no load).

2. Engine at idle and all electrical devices shut off. The engine shall be allowed to run long enough after starting to recharge the batteries prior to making these measurements.

3. Engine at idle and all electrical loads that normally run simultaneously turned on.

4. Engine at 50 percent of governed speed with all electrical loads that normally run simultaneously turned on.

5. Engine at governed speed with all electrical loads that normally run simultaneously turned on.

4-3.7.5 The electrical system performance shall be compared against the specification at engine idle and at 50 percent of engine rpm. The measured voltage of the batteries shall remain above 13 volts (for a 12-volt system) and 26 volts (for a 24-volt system) at all times while the alternator is running.

4-3.8 Radio Suppression.

4-3.8.1 Test facilities shall be in accordance with SAE J551, *Standard on Performance Levels and Methods of Measurement of Electromagnetic Radiation from Vehicles and Devices (30-1000 MH_z)*, or the equivalent standard being used.

4-3.8.2 Test equipment shall be in accordance with SAE J551, *Standard on Performance Levels and Methods of Measurement of Electromagnetic Radiation from Vehicles and Devices (30-1000 MH_z)*, or the equivalent standard being used.

4-3.8.3 The vehicle shall be configured with all standard electrical features mounted and operational. During the tests, all vehicle engines shall be operated at idle, and all vehicle-mounted electrical devices normally functioning at the crash site shall be turned on with the following stipulations:

(a) All vehicle lighting shall be on.

(b) All heating, defrosting, and air conditioning systems shall be on with their respective fans adjusted to the maximum speed setting.

(c) Auxiliary power generating devices (where applicable) shall be running.

(d) Intermittent warning devices, such as hazard flashers, warning buzzers, and horns, shall be turned off.

4-3.8.4 The vehicle shall be tested in accordance with SAE J551, *Standard on Performance Levels and Methods of Measurement of Electromagnetic Radiation from Vehicles and Devices (30-1000* MH_z*)*, or the equivalent standard being used.

4-3.8.5 The results of the test shall be evaluated in accordance with SAE J551, *Standard on Performance Levels and Methods of Measurement of Electromagnetic Radiation from Vehicles and Devices (30-1000* MH_z*)*, or the equivalent standard being used.

4-3.9 Gradability Test.

4-3.9.1 Test facilities shall consist of a site that includes a measured grade of 50 percent at least equal to the vehicle in length or a level, paved test pad adequate for an extended draw bar pull.

4-3.9.2 Test equipment shall consist of the following:

(a) A load cell accurate to within ± 500 lb (± 227 kg) (applicable only to the alternate draw bar method).

(b) A variable load dynamometer sled (applicable only to the alternate draw bar method).

4-3.9.3 The vehicle shall be tested in its fully loaded condition (*see definition of Fully Loaded Vehicle in Section 1-3*) with tires inflated to their recommended operating pressure.

4-3.9.4 The capability of the fully loaded vehicle (*see definition of Fully Loaded Vehicle in Section 1-3*) to ascend a 50-percent grade shall be demonstrated either on an actual grade or by means of an equivalent draw bar pull test. If an actual 50-percent grade is not available, then the vehicle shall be coupled to a 50-percent equivalent draw bar load determined as follows:

(a) A 50-percent grade — 26.57-degree angle.

(b) The loaded vehicle weight × sin 26.57 degrees (0.447) equals the necessary draw bar pull to simulate ascending a 50-percent grade.

(c) The area of the load cell shall be determined at the time of the test.

(d) The load cell reading, in psi (kPa), that simulates a 50-percent grade shall be calculated by the following:

$$\frac{\text{sin 26.57 degrees} \times \text{vehicle weight}}{\text{area of load cell}}$$

4-3.9.5 The vehicle shall negotiate the grade or draw pull smoothly and safely.

4-3.10 Body and Chassis Flexibility Test.

4-3.10.1 Test facilities shall consist of a flat test pad suitable for discharging agent and securing portable ramps under the vehicle.

4-3.10.2 Test equipment shall consist of two to four 14-in. (35.6-cm) ramps with flat tops large enough for the tire footprint and graduated on both sides to allow the vehicle to ascend and descend safely.

4-3.10.3 The vehicle shall be tested in its fully loaded condition (*see definition of Fully Loaded Vehicle in Section 1-3*) with tires inflated to their recommended operating pressure.

4-3.10.4 The vehicle shall be tested as follows:

(a) For a 4 × 4, drive the fully loaded vehicle onto 14-in. (35.6-cm) blocks positioned under the diagonally opposite front and rear wheels. For a 6 × 6, these correspond to axle 1 and axle 3. For an 8 × 8, these correspond to axle 1 and axle 4.

(b) With the vehicle in this position:

1. Inspect the vehicle thoroughly to ensure that there are no sheet metal interferences and that all moving parts are free to function.

2. Demonstrate all systems to ensure that they function normally, including discharge from all orifices.

(c) For a 6 × 6 and an 8 × 8, add a block under the second wheel of the bogie axle(s) so that both wheels on one side of the tandem axle are elevated simultaneously and diagonally opposite front and rear, and then repeat 4-3.10.4(b)1.

(d) Switch the blocks to the opposite sides of the truck and repeat 4-3.10.4(a) through (c).

4-3.10.5 No moving part shall interfere with another. If component contact should occur, it shall in no way damage the component or detract from the vehicle's ability to carry out its mission. No clearance shall be permitted between any tire and its supporting surface.

4-3.11 Service/Emergency Brake Test.

4-3.11.1 Test facilities shall consist of any dry, smooth, level, paved surface adequate in length to reach the respective test speeds and stop safely. The test area shall be marked so that a lane equivalent in width to that of the vehicle plus 4 ft (1.2 m) is established.

4-3.11.2 Instrumentation shall consist of the following:

(a) A calibrated fifth-wheel-type speed measuring device that is accurate to within ± 0.5 mph (± 0.8 km/h) or ± 0.5 percent of the actual vehicle speed;

(b) A ground speed readout device controlled by the fifth wheel;

(c) A trigger device that detects brake pedal movement;

(d) A strip chart recorder suitable for recording distance traveled, vehicle speed, and the point at which actuation of the brake system occurs.

4-3.11.3 The vehicle shall be tested in its fully loaded condition (*see definition of Fully Loaded Vehicle in Section 1-3*) with the brakes adjusted and the tires inflated to the vehicle manufacturer's recommended specifications. The brakes shall have been adequately burnished to ensure repeatable results.

4-3.11.4 The service and emergency brake stopping distances shall be determined in the following manner:

(a) While traveling down the center of the lane established by the width of the vehicle plus 4 ft (1.2 m), attain a speed slightly above the desired test speed and release the throttle.

(b) With the strip chart recorder running, at the instant that the vehicle reaches the desired test speed, actuate the brake pedal as if in a panic stop and continue applying the brakes until the vehicle comes to a complete stop. While stopped, modulate the brake pedal, as necessary, to maintain vehicle control. Record the distance traveled from the time that the brake pedal is applied to the time that the vehicle comes to rest.

(c) Observe whether or not the vehicle leaves the established lane during the brake stop.

(d) Repeat 4-3.11.4(a) through (c) for a total of five stops from each test speed.

(e) Repeat 4-3.11.4(a) through (d) to obtain results at speeds of 20 mph (32.2 km/h) and 40 mph (64.4 km/h).

(f) Disable the front service brakes and repeat 4-3.11.4(a) through (d) at a test speed of 40 mph (64.4 km/h).

(g) Reconnect the front service brakes and disable the rear service brakes and repeat 4-3.11.4(a) through (d) at a test speed of 40 mph (64.4 km/h).

4-3.11.5 Each of the recorded stops shall be within the specified distance without any part of the vehicle leaving the established test lane.

4-3.12 Service/Parking Brake Grade Holding Test.

4-3.12.1 Test facilities shall consist of dry, smooth, measured grades of 20 percent and 50 percent that are at least equal to the vehicle in length.

4-3.12.2 No instrumentation shall be required.

4-3.12.3 The vehicle shall be tested in its fully loaded condition (*see definition of Fully Loaded Vehicle in Section 1-3*) with the brakes adjusted and the tires inflated to the vehicle manufacturer’s recommended specifications. The brakes shall have been adequately burnished to ensure repeatable results.

4-3.12.4 The tests shall be conducted in the following manner:

(a) Drive the vehicle in a forward direction onto the 20-percent grade, stop, and set the parking brake.

(b) Shift the transmission to neutral and release the service brakes and verify that there is no wheel rotation.

(c) Repeat 4-3.12.4(a) and (b) with the vehicle facing the opposite direction.

(d) Drive the vehicle in a forward direction onto the 50-percent grade, apply the service brakes, and shift the transmission to neutral.

(e) Verify that there is no wheel rotation.

(f) Repeat 4-3.12.4(d) and (e) with the vehicle facing the opposite direction.

4-3.12.5 The brakes shall lock the wheels and hold the vehicle stationary on both the 20-percent and 50-percent grades with the vehicle pointed either uphill or downhill.

4-3.13 Steering Control Test.

4-3.13.1 Test facilities shall consist of any dry, level, paved surface that is free from loose material.

4-3.13.2 Test equipment shall consist of a steering wheel and a torque meter or a spring scale.

4-3.13.3 The vehicle shall be tested in a fully loaded condition (*see definition of Fully Loaded Vehicle in Section 1-3*) with tires inflated to their normal operating pressure.

4-3.13.4 The vehicle shall be tested as follows:

(a) Set the road wheels in the straight ahead position, engage neutral, and release the brakes, ensuring that there is no vehicle movement.

(b) With the engine at idle speed, measure and record the force applied to the steering rim that is necessary to turn the steering linkage from stop to stop.

4-3.13.5 The measured force shall not exceed the design specifications.

4-3.14 Vehicle Clearance Circle Test.

4-3.14.1 Test facilities shall consist of a level site having a dry, paved surface greater than three times the vehicle's length in diameter and shall be free from loose material.

4-3.14.2 A tape measure, markers or a marking device, and a calculator shall be required.

4-3.14.3 The vehicle's steering system shall be fully operational, and the steering linkage stops shall be adjusted within the manufacturer's specified production tolerance limits.

4-3.14.4 The vehicle shall be tested as follows:

(a) Drive the vehicle in a full cramp, making a left or right turn as necessary, in at least one complete circle to fully "settle" the wheels into their steady-state condition.

(b) Slowly drive the vehicle in the full cramp turn.

(c) Stop the vehicle in three locations around the turning circle, applying the brake smoothly and gradually.

(d) At each stop, mark the outermost projected point of the vehicle on the ground.

(e) Measure and record the straight line distances between the marks for each of the stop locations (length 1, length 2, and length 3).

(f) Calculate the vehicle clearance circle radius (R) as follows:

S = length 1 + length 2 + length 3

$$R = \frac{(\text{length } 1)(\text{length } 2)(\text{length } 3)}{4\,[S(S - \text{length } 1)(S - \text{length } 2)(S - \text{length } 3)]^{1/2}}$$

(g) Repeat 4-3.14.4(a) through (f) while turning the vehicle in the opposite direction.

4-3.14.5 The vehicle's clearance circle diameter (2R) shall be less than three times the maximum overall length of the vehicle.

4-3.15 Agent Pump(s)/Tank Vent Discharge Test.

4-3.15.1 Test facilities shall consist of a level, open site suitable for discharging agent. Access to a refill water supply shall be required.

4-3.15.2 Test equipment shall consist of a liquid level measuring device accurate to with ± 1.0 percent.

4-3.15.3 Each discharge nozzle on the vehicle shall have been individually verified as discharging at a flow rate at or above the minimum rate specified when the agent system is operated at the recommended pressure.

4-3.15.4 The test shall be conducted as follows:

(a) Fill the water and the foam tank to the top.

(b) Set the foam proportioning system to proportion foams at the concentration specified, and set the agent selector for the foam mode.

(c) Set the agent system pressure relief to the recommended pressure.

(d) Engage the agent pumps and operate them at maximum pumping speed with all discharge outlets closed.

(e) Simultaneously initiate discharge of the primary roof turret(s), primary hand lines, ground sweeps/bumper turret, and undertruck nozzles. After approximately 75 percent of the contents from the water tank has been discharged, simultaneously stop discharge through all nozzle outlets. Record the time of discharge.

(f) Measure and then add together the total amount of liquid discharged from the water tank and the foam tank. Calculate the average discharge rate using the discharge time from 4-3.15.4(e).

(g) Calculate the quantity of liquid used from the foam tank as a percentage of the total liquid discharged.

4-3.15.5 The measured total discharge rate shall be equal to at least the sum of the minimum specified discharge rates of the nozzles used during the test. A calculated average foam concentration within the tolerance permitted for the respective foam type confirms the adequacy of the foam-liquid concentrate piping to supply foam at a rate compatible with the maximum discharge requirements of the vehicle.

4-3.16 Water Tank Fill and Overflow Test.

4-3.16.1 Test facilities shall consist of a level site with pumping or hydrant capacity, or both, sufficient to provide the water delivery rate needed to fill the water tank in 2 minutes at an inlet pressure of 80 psi (551.6 kPa).

4-3.16.2 Instrumentation shall consist of calibrated mechanical or electronic pressure measuring devices with an accuracy of ± 3 percent and a stopwatch.

4-3.16.3 The water tank shall be empty, and the water tank fill and vent system shall be fully operational for this test.

4-3.16.4 The water tank fill and vent system shall be tested as follows to verify that the tank can be filled in 2 minutes or less:

(a) Park the vehicle on level ground.

(b) Attach one pressure measuring device at the inlet to the tank fill piping, and attach the other pressure measuring device to the tank body or an extension of the tank body.

(c) Simultaneously initiate flow to the tank and start the stopwatch. The water supply pressure shall be maintained at 80 psi (551.6 kPa) throughout the test.

(d) At the moment water begins to flow from the overflow piping, stop the watch and record the elapsed time.

(e) While maintaining an 80 psi (551.6 kPa) supply pressure and an overflow condition, record the internal tank pressure. After recording this pressure, shut off the water supply.

4-3.16.5 The results of this test shall be evaluated as follows:

(a) The time to fill the tank to the overflow condition shall be 2 minutes or less.

(b) The internal tank pressure shall not exceed the tank design pressure.

4-3.17 Flushing System Test.

4-3.17.1 Test facilities shall consist of an open site suitable for discharging agent and draining the vehicle. Access to a refill water supply shall be required.

4-3.17.2 No special instrumentation shall be required for this test.

4-3.17.3 The vehicle's agent system and flushing system shall be fully operational for this test.

4-3.17.4 The vehicle's flushing system shall be tested as follows:

(a) Fill the water tank and foam tank with clean water and add dye to the foam tank.

(b) Discharge agent through each discharge orifice on the vehicle while operating in the foam mode until dye is present in the discharge stream.

(c) Mark the liquid level in the foam tank.

(d) Set the agent system in the flush mode and discharge through each discharge orifice until clear water is present in the discharge stream.

(e) Shut the agent system down and drain the piping.

(f) Recheck the foam tank level.

4-3.17.5 Failure to develop a clear water stream through each nozzle shall be considered evidence that the flushing system is inadequate. There shall be no evidence of feedback of clear water into the foam tank.

4-3.18 Roof Turret Flow Rate Test.

4-3.18.1 Test facilities shall consist of a level, open site suitable for discharging agent. Access to a refill water supply shall be required.

4-3.18.2 Test equipment shall consist of the following:

(a) A calibrated sight gauge;

(b) A liquid volume measuring device accurate to within ± 1.0 percent;

(c) A calibrated pressure gauge, if not already provided on the truck;

(d) *Alternative:* A stopwatch and a scale capable of measuring total vehicle weight accurate to within ± 1.0 percent.

4-3.18.3 It shall have been verified that the vehicle's pumping system is capable of operating at full rate.

4-3.18.4 The roof turret discharge rate shall be determined as follows:

(a) Set the roof turret pattern for straight stream operation.

(b) Fill the water tank completely.

(c) Engage the pump and operate it at design speed.

(d) Open the turret flow control valve.

(e) The following procedures also shall be performed, as necessary:

1. If flow meters are used, read and record the flow rate once the discharge pressure stabilizes.

2. If a sight gauge is used, read and record the tank volume in gallons while simultaneously starting a stopwatch after the discharge pressure stabilizes. Read and record the tank volume in gallons when the watch is stopped after allowing flow for at least 1 minute. Determine the flow rate in gpm by dividing the difference in gallons by the time of discharge.

3. If a scale is used, record the vehicle weight prior to discharge. Start a stopwatch and discharge water at stabilized pressure for 1 minute. Record the vehicle weight after discharge and calculate the flow rate.

(f) Reset the roof turret pattern to the dispersed setting and repeat 4-3.18.4(b) through (e).

(g) Reset the roof turret to the half flow rate setting (if applicable) and repeat 4-3.18.4(a) through (f).

4-3.18.5 The measured turret flow rates shall equal the specified flow rate within a tolerance of +10 percent/ –0 percent.

4-3.19 Roof Turret Pattern Test.

The roof turret pattern test shall be conducted in accordance with the requirements of NFPA 412, *Standard for Evaluating Aircraft Rescue and Fire Fighting Foam Equipment*, and the results shall be evaluated in accordance with the vehicle specifications.

4-3.20 Roof Turret Control Force Measurement.

4-3.20.1 Test facilities shall consist of a level, open site suitable for discharging agent. Access to a refill water supply shall be required.

4-3.20.2 Test equipment shall consist of a spring scale that can be attached to the end of the turret control handle or a torque measuring device that can be attached to the rotational axis of the turret.

4-3.20.3 The water tank shall be filled prior to starting the test, and it shall have been verified that the vehicle pump system is capable of operating at design flow and pressure. The test shall be conducted with the roof turret at the full flow rate setting. The turret power-assist system, if applicable, shall be fully operational.

4-3.20.4 The test shall be conducted as follows:

(a) Set the turret pattern control for straight stream and, where applicable, engage the power assist.

(b) Engage the pump and operate it at design speed.

(c) Open the turret flow control valve.

(d) Using a spring scale attached to the end of the turret aiming handle, rotate the turret to the right and to the left, recording the needed force for each direction. Again, using the spring scale attached to the end of the turret aiming handle, elevate and depress the turret and record the force needed to elevate and depress.

(e) Repeat 4-3.20.4(b) through (d) with the pattern control set at the maximum dispersed position after refilling the water tank as necessary.

4-3.20.5 The forces recorded shall not exceed the forces specified.

4-3.21 Roof Turret Articulation Test.

4-3.21.1 Test facilities shall consist of a level, open site suitable for discharging agent. Access to a refill water supply shall be required.

4-3.21.2 The test equipment shall consist of a tape measure, a level, and a protractor.

4-3.21.3 The water tank shall be filled prior to the test, and the turret power-assist system, if applicable, shall be fully operational.

4-3.21.4 The test shall be conducted as follows:

(a) With the turret pointed ahead, raise the turret barrel to the maximum elevated position. With a level held horizontal at the vertical rotation axis, measure the angle between the level and the turret barrel with the protractor and record.

(b) Rotate the roof turret barrel to the right and left to the angle needed.

(c) Place a marker 30 ft (9.1 m) in front of the vehicle. Aim the turret straight ahead with the rate control at full flow, with the pattern control in the maximum dispersed position, and with the turret in the maximum depressed position. When water discharges, observe whether water strikes the marker or strikes closer to the vehicle.

4-3.21.5 Turret articulation shall be considered acceptable if the measurements meet or exceed the specifications.

4-3.22 Hand Line Nozzle Flow Rate Test.

4-3.22.1 Test facilities shall consist of a level, open site suitable for discharging agent. Access to a refill water supply shall be required.

4-3.22.2 Test equipment shall consist of the following:

(a) A calibrated sight gauge;

(b) A liquid volume measuring device accurate to within ± 1.0 percent;

(c) A calibrated pressure gauge, if not already provided on the truck;

(d) *Alternative:* A stopwatch and a scale capable of measuring total vehicle weight accurate to within ± 1.0 percent.

4-3.22.3 It shall have been verified that the vehicle's pumping system is capable of operating at full rate.

4-3.22.4 The hand line nozzle flow rate shall be determined as follows:

(a) Set the hand line nozzle pattern for straight stream operation.

(b) Fill the water tank completely.

(c) Engage the pump and operate it at design speed.

(d) Open the hand line nozzle flow control valve.

(e) The following procedures also shall be performed, as necessary:

1. If flow meters are used, read and record the flow rate once the discharge pressure stabilizes.

2. If a sight gauge is used, read and record the tank volume in gallons while simultaneously starting a stopwatch after the discharge pressure stabilizes. Read and record the tank volume in gallons when the watch is stopped after allowing flow for at least 5 minutes. Determine the flow rate in gpm by dividing the difference in gallons by the time of discharge.

3. If an open top calibrated tank is used, discharge through the nozzle until the pressure stabilizes, and then simultaneously direct the stream into the tank while starting the stopwatch. Stop the stopwatch when the tank is full and remove or shut off the nozzle. Determine the flow rate by dividing the tank volume in gallons by the fill time in minutes.

4. If a scale is used, record the vehicle weight prior to discharge. Start a stopwatch and discharge water at stabilized pressure for 1 minute. Record the vehicle weight after discharge and calculate flow rate.

(f) If the nozzle is the nonair-aspirated type, repeat 4-3.22.4(b) through (e) with the nozzle pattern setting in the fully dispersed position.

4-3.22.5 The measured hand line nozzle flow rates shall equal the specified flow rate within a tolerance of +10 percent/–0 percent.

4-3.23 Hand Line Nozzle Pattern Test.

The hand line nozzle pattern test shall be conducted in accordance with the requirements of NFPA 412, *Standard for Evaluating Aircraft Rescue and Fire Fighting Foam Equipment*, and the results shall be evaluated in accordance with the vehicle specifications.

4-3.24 Ground Sweep/Bumper Turret Flow Rate Test.

4-3.24.1 Test facilities shall consist of an open site suitable for discharging agent. Access to a refill water supply shall be required.

4-3.24.2 Test equipment shall consist of the following:

(a) A calibrated sight gauge;

(b) A liquid volume measuring device accurate to within ± 1.0 percent;

(c) A calibrated pressure gauge, if not already provided on the truck;

(d) *Alternative:* A stopwatch and a scale capable of measuring total vehicle weight accurate to within ± 1.0 percent.

4-3.24.3 It shall have been verified that the vehicle's pumping system is capable of operating at full rate.

4-3.24.4 The ground sweep/bumper turret discharge rate shall be determined as follows:

(a) Set the ground sweep/bumper turret pattern for straight stream operation.

(b) Fill the water tank completely.

(c) Engage the pump and operate it at design speed.

(d) Open the ground sweep/bumper turret flow control valve.

(e) The following procedures also shall be performed, as necessary:

1. If flow meters are used, read and record the flow rate once the discharge pressure stabilizes.

2. If a sight gauge is used, read and record the tank volume in gallons while simultaneously starting a stopwatch after the discharge pressure stabilizes. Read and record the tank volume in gallons when the watch is stopped after allowing flow for at least 1 minute. Determine the flow rate in gpm by dividing the difference in gallons by the time of discharge.

3. If a scale is used, record the vehicle weight prior to discharge. Start a stopwatch and discharge water at stabilized pressure for 1 minute. Record the vehicle weight after discharge and calculate the flow rate.

(f) If the ground sweep/bumper turret is the nonair-aspirated type, repeat 4-3.24.4(b) through (e) with the nozzle pattern setting in the fully dispersed position.

4-3.24.5 The measured flow rates shall equal the specified flow rate within a tolerance of +10 percent/–0 percent.

4-3.25 Ground Sweep/Bumper Turret Pattern Test.

The ground sweep/bumper turret pattern test shall be conducted in accordance with the requirements of NFPA 412, *Standard for Evaluating Aircraft Rescue and Fire Fighting Foam Equipment*, and the results shall be evaluated in accordance with the vehicle specifications.

4-3.26 Undertruck Nozzle Test.

4-3.26.1 Test facilities shall consist of an open site suitable for discharging agent.

4-3.26.2 Markers shall be available for use in defining the pattern boundaries.

4-3.26.3 It shall have been verified that the vehicle's pump system is capable of operating at full rate, and the agent tanks shall be filled with water and foam, respectively.

4-3.26.4 The test shall be conducted as follows:

(a) Set the agent system to operate in the foam mode.

(b) Engage the agent pump and operate it at design speed.

(c) Open the undertruck nozzles to discharge simultaneously, and continue to discharge until a definite pattern outline is apparent.

(d) Close the discharge and mark and record the boundaries of the pattern.

4-3.26.5 The pattern shall be considered acceptable if the foam spray covers the outline created by the vehicle on the ground and wets the inside of all tires.

4-3.27 Foam Concentration/Foam Quality Test.

4-3.27.1 Test facilities shall consist of an open site suitable for discharging agent. Access to a refill water supply and a foam concentrate supply shall be required.

4-3.27.2 The test equipment described in NFPA 412, *Standard for Aircraft Rescue and Fire Fighting Foam Equipment*, shall be used for this test.

4-3.27.3 Each discharge nozzle on the vehicle shall have been individually verified as discharging at a flow rate within the tolerance specified. The agent system shall have been verified as capable of operating at full rate.

4-3.27.4 The test shall be conducted as follows:

(a) Fill the water tank and the foam tank to the top and refill as necessary throughout the test.

(b) Set the foam proportioning system to proportion foams at the concentration specified, and set the agent selector for the foam mode.

(c) Set the agent system pressure relief to the recommended pressure.

(d) Engage the agent pumps and operate them at maximum pumping speed with all discharge outlets closed.

(e) Each foam delivery system shall be tested first for the individual nozzle/flow rate specified in the following list and then for a total combined simultaneous discharge in accordance with NFPA 412, *Standard for Evaluating Aircraft Rescue and Fire Fighting Foam Equipment*:

1. Roof turret(s) full rate;
2. Roof turret(s) half rate;
3. Ground sweep/bumper turret;
4. Hand line nozzles;
5. Undertruck nozzles.

4-3.27.5 The foam concentrations measured shall fall within the permitted tolerances specified in NFPA 412, *Standard for Evaluating Aircraft Rescue and Fire Fighting Foam Equipment*, for each nozzle and for the combined simultaneous discharge. The foam expansion and drainage time measurements shall equal or exceed those specified in NFPA 412 for each nozzle.

4-3.28 Warning Siren Test.

4-3.28.1 Test facilities shall consist of a flat, open area that is free from any large reflecting surfaces (such as other vehicles, signboards, or hills) within a 200-ft (61-m) radius of the vehicle.

4-3.28.2 Test equipment shall consist of the following:

(a) A sound level meter that meets the requirements of ANSI S1.4, *Specification for Sound Level Meters*, for Type 1 or S1A meters. The sound level meter shall have been calibrated by a certified testing laboratory within the previous 12 months.

(b) A tape measure.

4-3.28.3 The vehicle's siren speaker shall be mounted in its proper location and shall be in working order.

4-3.28.4 The capability of the warning siren on the vehicle to project sound forward and to the sides shall be determined as follows:

(a) Set the sound level meter to the A-weighing network, "fast" meter response, and position the meter directly ahead of the vehicle at a distance of 100 ft (30.5 m) from the front bumper. The microphone shall be at ear level.

(b) Energize the siren and record the meter reading.

(c) Repeat 4-3.28.4(a) and (b) with the sound level meter 100 ft (30.5 m) from the vehicle, first at a position 45 degrees to the right and then at 45 degrees to the left of the longitudinal centerline of the vehicle.

4-3.28.5 The recorded noise level shall equal or exceed the specifications.

4-3.29 Propellant Gas.

4-3.29.1 Test facilities shall consist of an open site suitable for discharging AFFF, dry chemical, or halon agent.

4-3.29.2 Test equipment shall consist of a calibrated scale or load cell with an accuracy of ± 1.0 percent.

4-3.29.3 The vehicle extinguishing agent piping system shall be operational, and the agent tank(s) shall be empty. The propellant gas tank(s) shall be fully charged and within proper pressure. A means of lifting the agent tanks for weighing without loss of agent shall be provided. Alternatively, the extinguishing agent tank(s) shall be permitted to be tested outside of the vehicle. Where this alternative is used, the test shall be conducted with the agent tank(s) and related piping, fittings, valves, hose, and nozzle(s) in the same configurations in which they are installed on the vehicle.

4-3.29.4 The test for each of the extinguishing agents shall be conducted in the following manner:

(a) Weigh the empty tank(s) and record as tare weight.

(b) Using the manufacturer's recommended filling procedure, charge the tank(s) with the manufacturer's recommended extinguishing agent to the upper fill weight/volume tolerance. Reweigh and record this as gross filled weight.

(c) Ensure that all fill caps are tightened securely, all propellant gas lines are connected, the discharge nozzle(s) is in the closed position, and all fittings and connections are tight.

(d) Pressurize the agent tank(s) using the manufacturer's recommended procedure.

(e) Simultaneously, fully open all discharge nozzles and keep open until only the pressurizing gas is expelled.

(f) Shut down the propellant gas supply.

(g) Reweigh the agent tank(s) and record this as post-discharge weight.

(h) Calculate and record the total agent discharged as follows:

Gross filled weight – post-discharge weight = total agent discharge.

4-3.29.5 There shall be a sufficient supply of propellant gas to purge all discharge lines as evidenced by the emission from each nozzle of gas only. The total agent discharged shall equal or exceed the design capacity.

4-3.30 Pressure Regulation.

4-3.30.1 Test facilities shall consist of an open site suitable for discharging the AFFF, dry chemical, or halon agent.

4-3.30.2 Test equipment shall consist of a calibrated pressure gauge or transducer capable of reading the recommended tank top discharge pressure and possessing an accuracy of ± 5.0 psi (± 34.5 kPa).

4-3.30.3 The vehicle extinguishing agent system shall be piped to all discharge outlets with the tank(s) empty. The propellant gas tank(s) shall be fully charged and at proper pressure. A means for mounting a pressure gauge or transducer somewhere between the downstream (low pressure) side of the regulator and the agent tank top shall be provided. Alternatively, the extinguishing agent tank(s) shall be permitted to be tested outside of the vehicle. Where this alternative is used, the test shall be conducted with the agent tank(s) and related piping, fittings, valves, hose, and nozzle(s) in the same configuration in which they are installed on the vehicle.

4-3.30.4 The test for each of the extinguishing agents shall be conducted in the following manner:

(a) Using the manufacturer's recommended filling procedure, charge the tank(s) with the manufacturer's recommended extinguishing agent to the upper fill weight/volume tolerance.

(b) Install a pressure gauge or transducer between the downstream (low pressure) side of the regulator and the agent tank top.

(c) Ensure that all fill caps are tightened securely, all propellant gas lines are connected, the discharge nozzle(s) is in the closed position, and all fittings are tight.

(d) Pressurize the agent tank(s) using the manufacturer's recommended procedure. Record the agent tank pressure.

(e) Simultaneously, fully open all discharge nozzles and keep open until only the pressurizing gas is expelled.

(f) During agent discharge, monitor agent tank pressure and record at 5-second or shorter intervals.

(g) Once the gas point has been reached for all discharge nozzles, shut down the gas supply.

4-3.30.5 The pressure regulation system shall be capable of maintaining pressure throughout the discharge. At no time shall pressure fall below or exceed the design range specified by the manufacturer.

4-3.31 AFFF Premix Piping and Valves.

4-3.31.1 Test facilities shall consist of a level, open site suitable for discharging the agent and measuring ranges.

4-3.31.2 Test equipment shall consist of the following:

(a) A calibrated scale or load cell with an accuracy of ± 1.0 percent;

(b) A stopwatch.

4-3.31.3 All vehicle foam discharge piping shall be operational, and the premix tank shall be empty. The propellant gas tank(s) shall be fully charged and within proper pressure. A means of lifting the agent tank(s) for weighing without loss of agent shall be provided. Alternatively, the system shall be permitted to be tested outside of the vehicle. Where this alternative is used, the test shall be conducted with the premix tank and related piping, fittings, valves, hose, and nozzle(s) in the same configuration in which they are installed on the vehicle.

4-3.31.4 The test shall be conducted in the following manner:

(a) Weigh the empty premix tank and record as tare weight.

(b) Using the manufacturer's recommended filling procedure, charge the tank with water or premix solution. Reweigh and record as gross filled weight.

(c) Ensure that all fill caps are tightened securely, all propellant gas lines are connected, the discharge nozzle(s) is in the closed position, and all fittings and connections are tight.

(d) Pull all hand line hose from the reel(s) or hose compartment(s).

(e) Pressurize the system using the manufacturer's recommended procedure.

(f) Simultaneously, start the stopwatch and fully open the turret(s), undertruck nozzles, and hand line(s).

(g) After discharging for at least 30 seconds, simultaneously stop the stopwatch and close the turret(s), undertruck nozzles, and hand line(s). Record the elapsed time on the stopwatch as discharge time.

(h) Following the manufacturer's instructions, shut off the propellant gas supply and blow down the system.

(i) Reweigh the premix tank and record this as post-discharge weight.

(j) Add the recommended flow rates from each discharge nozzle and record this sum as the designed total flow rate.

(k) Calculate the actual total flow rate as follows:

$$\frac{\text{gross filled weight} - \text{post-discharge weight}}{(\text{density}) \times \frac{(\text{elapsed time in seconds})}{60}} = \text{actual total flow rate}$$

4-3.31.5 The actual total flow rate shall equal the specified designed total flow rate within a tolerance of + 10 percent/ –0 percent.

4-3.32 Pressurized Agent Purging and Venting.

4-3.32.1 Test facilities shall consist of an open site suitable for discharging AFFF, dry chemical, or halon agent.

4-3.32.2 No special test equipment or instrumentation shall be required to conduct the test(s).

4-3.32.3 The vehicle extinguishing agent system(s) shall be fully operational, and the agent tank(s) shall be fully charged with the manufacturer's recommended agent. The propellant gas tank(s) shall be fully charged and within proper pressure. Alternatively, the extinguishing agent tank(s) shall be permitted to be tested outside of the vehicle. Where this alternative is used, the test shall be conducted with the fully charged agent tank(s) and related piping, fittings, valves, hose, and nozzle(s) in the same configuration in which they are installed on the vehicle.

4-3.32.4 The test for each of the pressurized extinguishing agent systems shall be conducted in the following manner:

(a) Pressurize the agent tank(s) using the manufacturer's recommended procedure.

(b) Pull all hose from the reel(s) or compartment(s).

(c) Fully open all discharge devices.

(d) After approximately 5 seconds to 20 seconds, close all discharge devices.

(e) Purge all discharge lines and vent the agent tank(s) using the manufacturer's recommended procedure.

4-3.32.5 Any agent beyond the tank outlet shall be purged from the discharge piping and hose as evidenced by the discharge from each nozzle of gas only. The depressurization or venting of the agent tank shall allow only minimal quantities of agent to escape.

4-3.33 Auxiliary Agent Hand Line Flow Rate and Range.

4-3.33.1 Test facilities shall consist of a level, open site suitable for discharging the dry chemical or halon agent and measuring ranges. Wind conditions shall be calm [less than 5 mph (8 km/h)].

4-3.33.2 Test equipment shall consist of the following:

(a) A calibrated scale or load cell with an accuracy of ± 1.0 percent;

(b) A stopwatch;

(c) A tape measure or other device for measuring distance;

(d) A calibrated anemometer;

(e) A pan containing at least 1 ft^2 (0.09 m^2) of motor or aviation gasoline.

4-3.33.3 All vehicle agent piping shall be operational, and the agent tank shall be empty. The propellant gas tank(s) shall be fully charged and within proper pressure. A means of lifting the agent tank(s) for weighing without loss of agent shall be provided. Alternatively, the system shall be permitted to be tested outside of the vehicle. Where this alternative is used, the test shall be conducted with the agent tank and related piping, fittings, valves, hose, and nozzle(s) in the same configuration in which they are installed on the vehicle.

4-3.33.4 The test shall be conducted in the following manner:

(a) Using the manufacturer's recommended agent and filling procedure, charge the agent tank.

(b) Ensure that all fill caps are tightened securely, all propellant gas lines are connected, the discharge nozzle(s) is in the closed position, and all fittings and connections are tight.

(c) Pull all hand line hose from the reel(s).

(d) Pressurize the system using the manufacturer's recommended procedure and open all hand line nozzles until agent flow is observed. Close the nozzles.

(e) Weigh and record the agent tank as the "initial weight."

(f) Position the hand line nozzles at least 20 ft (6.1 m) from the fire pan so that they can be discharged onto a flat grade with no stream obstructions. Ignite the fuel.

(g) Select one of the hand line nozzles (nozzle 1). While holding it in a position 3 ft to 4 ft (0.9 m to 1.2 m) above ground level, simultaneously start the stopwatch and fully open the nozzle, and then discharge agent onto the fire.

(h) After at least 50 percent of the contents of the tank has been discharged, shut down the nozzle and stop the stopwatch. Record the time as "elapsed discharge time no. 1."

(i) Reweigh the agent tank and record as "weight after first discharge."

(j) If a second nozzle (nozzle 2) is provided, repeat 4-3.33.4(a) through (h).

(k) While holding the two hand line nozzles in a fixed horizontal position 3 ft to 4 ft (0.9 m to 1.2 m) above ground level, simultaneously start the stopwatch and fully open both nozzles.

(l) After at least 50 percent of the contents of the tank has been discharged, simultaneously shut down both nozzles and stop the stopwatch. Record the time as "elapsed discharge time no. 2."

(m) Reweigh the agent tank and record as "weight after second discharge."

(n) Calculate the flow rate from nozzle 1 as follows:

$$\frac{\text{initial weight (test 1)} - \text{initial weight (test 2)}}{\text{(elapsed discharge time no. 1)}} = \text{flow rate}$$

(o) Calculate the flow rate from nozzle 2 as follows:

$$\frac{\text{weight after first discharge} \qquad \text{weight after second discharge}}{2 \times \text{(elapsed discharge time no. 2)}} = \text{flow rate}$$

(p) If nozzle 2 is of a different configuration, repeat the fire test for this nozzle.

4-3.33.5 Test results shall be evaluated as follows:

(a) The flow rate from each nozzle shall meet the requirement.

(b) The range from each nozzle shall meet or exceed the requirements as evidenced by extinguishment of the fire(s).

(c) When discharged simultaneously, the flows from nozzle 1 and nozzle 2 shall be within 10 percent of each other.

4-3.34 Dry Chemical Turret Flow Rate and Range.

4-3.34.1 Test facilities shall consist of a level, open site suitable for discharging the agent and measuring range. The test shall be conducted in calm wind [less than 5 mph (8 km/h)].

4-3.34.2 Test equipment shall consist of the following:

(a) A calibrated scale or load cell with an accuracy of ± 1.0 percent;

(b) A stopwatch;

(c) A tape measure or other device for measuring distance;

(d) A calibrated anemometer.

4-3.34.3 All dry chemical discharge piping shall be operational, and the dry chemical tank shall be empty. The propellant gas tank(s) shall be fully charged and within proper pressure. A means of lifting the agent tank(s) for weighing without loss of agent shall be provided. Alternatively, the system shall be permitted to be tested outside of the vehicle. Where this alternative is used, the test shall be conducted with the agent tank and related piping, fittings, valves, hose, and nozzle(s) in the same configuration in which they are installed on the vehicle.

4-3.34.4 The test shall be conducted in the following manner:

(a) Using the manufacturer's recommended agent and filling procedure, charge the tank.

(b) Ensure that all fill caps are tightened securely, all propellant gas lines are connected, the discharge nozzle(s) is in the closed position, and all fittings and connections are tight.

(c) Pressurize the system using the manufacturer's recommended procedure and open the turret discharge valve until agent is observed. Close the valve.

(d) Weigh and record the agent tank as the "initial test weight."

(e) Position the dry chemical turret so that it can be discharged onto a flat grade with no stream obstructions. Position the turret to obtain maximum straight stream reach.

(f) Simultaneously, start the stopwatch and fully open the turret.

(g) During discharge, place markers at the far point where significant dry chemical strikes the ground (range marker) and at either side of the widest part of the pattern (width markers).

The operator(s) placing the markers shall wear proper safety equipment for this task. The agent manufacturer's material safety data sheet shall be consulted.

(h) After discharging at least 75 percent of the contents of the tank, simultaneously stop the stopwatch and shut down the turret. Record the elapsed time in seconds as discharge time.

(i) Measure the distance from the turret to the range marker and record as the far point range.

(j) Measure the distance between the width markers and record as the pattern width.

(k) Reweigh the agent tank and record as the weight after discharge.

(l) Calculate the flow rate as follows:

$$\frac{\text{initial test weight} - \text{weight after discharge}}{\text{elapsed discharge time}} = \text{flow rate}$$

4-3.34.5 The stream range and pattern width shall equal or exceed the requirements. The discharge flow rate shall equal the requirement.

4-3.35 Cab Interior Noise Test.

4-3.35.1 Test facilities shall consist of a flat, open, paved area suitable for operating the vehicle at a constant speed of 50 mph (80.5 km/h) that is free from any large reflecting surfaces (such as other vehicles, signboards, or hills) within a 50-ft (15.2-m) distance of the vehicle. The wind speed shall not exceed 15 mph (24.1 km/h) during the test.

4-3.35.2 Test equipment shall consist of a sound level meter that meets the requirements of ANSI S1.4, *Specification for Sound Level Meters*, for Type 1 or S1A meters. The sound level meter shall have been calibrated by a certified testing laboratory within the previous 12 months.

4-3.35.3 The vehicle shall be tested in its fully loaded condition (*see definition of Fully Loaded Vehicle in Section 1-3*) with tires inflated to their recommended inflation pressure. The cab doors, windows, and hatch openings shall be closed during this test. The vehicle shall be driven long enough to bring the drive train components up to their normal operating temperatures prior to starting the test. Thermostatically controlled shutters or cooling fans, or both, shall be allowed to function normally. The vehicle agent system(s), the communications system, and the audible warning system and emergency warning system shall be inactive during this test.

4-3.35.4 The interior noise level of the cab shall be determined as follows:

(a) Set the sound level meter to the A-weighing network, “fast” meter response, and position the meter adjacent to the driver’s ear.

(b) Bring the vehicle up to a road speed of 50 mph (80.5 km/h) and maintain that speed while recording the noise measurements.

(c) Repeat 4-3.35.4(a) and (b) until four readings have been taken, bringing the vehicle to rest between each measurement. If any of the noise measurements differ from the others by more than 2 dBA, they should be replaced by another measurement, since they could be the result of extraneous ambient noises or equipment/measurement error.

(d) Average the four readings.

4-3.35.5 The average of the recorded noise readings shall be less than or equal to the cab interior noise level specification.

4-4 Operational Tests.

4-4.1 Weight/Weight Distribution.

4-4.1.1 Test facilities shall consist of an in-ground, certified weight scale large enough to accommodate the vehicle or a level test pad suitable for positioning the truck on top of portable wheel scales.

4-4.1.2 Instrumentation for this test is limited to the in-ground or portable scales. The accuracy of the scales shall be ± 1.0 percent.

4-4.1.3 The vehicle shall be tested in its fully loaded condition (*see definition of Fully Loaded Vehicle in Section 1-3*). Ballast shall be used for the crew and equipment as necessary.

4-4.1.4 The total weight of the vehicle and weight distribution shall be determined as follows:

(a) Determine the total weight of the vehicle by driving the fully loaded vehicle onto the scale(s).

(b) Determine the individual axle loadings by measuring the weight on each axle at the ground. Since the total vehicle weight is more accurately reflected by the single weight measurement in 4-4.1.4(a), correct the individual axle loads proportionately, as necessary, so that their total equals the total vehicle weight. Subtract the lightest loaded axle weight from the heaviest loaded axle weight, and divide the difference by the weight of the heaviest axle.

(c) Determine individual tire loadings by measuring the weight on each tire at the ground. Make proportionate corrections to the individual tire loads so that their total equals the load on the respective axle. Determine the average tire weight for each axle by adding the right-hand and left-hand tire weights for each axle and dividing by 2. Subtract the lightest loaded tire weight from the heaviest loaded tire weight for each axle, and divide the difference by the average tire load for that axle.

4-4.1.5 The data shall be evaluated on the following basis:

(a) The total weight of the vehicle shall be less than or equal to the vehicle manufacturer’s gross vehicle weight rating.

(b) The difference between the heaviest loaded axle and the lightest loaded axle shall be less than or equal to the maximum difference permitted in the specification.

(c) The difference between the tire weights on any given axle shall be less than or equal to the maximum difference permitted in the specification.

4-4.2 Acceleration.

4-4.2.1 Test facilities shall consist of a dry, straight, level paved surface sufficient in length to accelerate the vehicle from rest to 50 mph (80.5 km/h) and then bring it to a safe stop.

Ambient temperatures at the test site shall be 0°F to 110°F (–17.8°C to 43.3°C), and elevations shall include heights up to 2000 ft (609.6 m) unless otherwise specified by the purchaser.

4-4.2.2 Instrumentation shall consist of the vehicle’s speedometer and tachometer, as installed by the manufacturer at the time of delivery, and a stopwatch.

4-4.2.3 The vehicle shall be tested in its fully loaded condition (*see definition of Fully Loaded Vehicle in Section 1-3*) with the engine and the transmission at their normal operating temperatures. The tires shall be inflated to the manufacturer’s recommended pressure.

4-4.2.4 The test shall be conducted in the following manner:

(a) Start the test with the vehicle at rest, the engine at idle, and the transmission in gear.

(b) Simultaneously, start the stopwatch and accelerate the vehicle and continue accelerating to a wide-open throttle condition.

(c) At the moment the vehicle reaches 50 mph (80.5 km/h), stop the watch and record the elapsed time.

(d) To compensate for wind conditions and slope, repeat the test in the opposing direction. Record and average a minimum of three readings in each of the two directions.

4-4.2.5 The average acceleration time to 50 mph (80.5 km/h) shall be less than or equal to the requirement, as specified.

4-4.3 Top Speed.

4-4.3.1 Test facilities shall consist of a dry, paved, level surface suitable for achieving a vehicle speed of at least 65 mph (104.6 km/h) and bringing the vehicle to a safe stop.

4-4.3.2 Instrumentation shall consist of the vehicle’s speedometer as installed by the manufacturer at the time of delivery.

4-4.3.3 The vehicle shall be tested in its fully loaded condition (*see definition of Fully Loaded Vehicle in Section 1-3*) with the engine and the transmission at their normal operating temperatures. The tires shall be inflated to the manufacturer’s recommended pressure.

4-4.3.4 The test shall be conducted in the following manner:

(a) Accelerate the vehicle to a speed of at least 65 mph (104.6 km/h).

(b) To compensate for wind conditions and slope, repeat the test in the opposing direction.

(c) If 65 mph (104.6 km/h) cannot be achieved in one of the directions, repeat 4-4.3.4(a) and (b), accelerating the vehicle to its maximum speed in each direction, record the speeds, and average the two numbers.

4-4.3.5 The test shall be considered successful if the average top speed equals or exceeds 65 mph (104.6 km/h).

4-4.4 Brake Operational Test.

4-4.4.1 Test facilities shall consist of any dry, smooth, paved surface adequate in length to reach the respective test speeds and stop safely. The test area shall be marked so that a lane that equals the width of the vehicle plus 4 ft (1.2 m) is established. A runway or taxiway with a marked centerline shall be permitted to be used.

4-4.4.2 Instrumentation shall consist of the vehicle's speedometer, as installed by the manufacturer, and a tape measure.

4-4.4.3 The vehicle shall be tested in its fully loaded condition (*see definition of Fully Loaded Vehicle in Section 1-3*) with the brakes adjusted to the manufacturer's recommended tolerances. The tires shall be inflated to the vehicle manufacturer's recommended inflation pressure. The vehicle's stopping distance shall have been certified by the vehicle manufacturer.

4-4.4.4 The test shall be conducted in the following manner:

(a) Maintain a constant speed of 20 mph (32.2 km/h) while driving down the centerline of the test site.

(b) Apply the brakes as if in a panic stop until the vehicle comes to rest.

(c) Measure and record the distance from the outer edge of the vehicle to the centerline of the lane.

(d) Repeat 4-4.4.4(a) through (c) at a constant speed of 40 mph (64.4 km/h).

4-4.4.5 The distance measured shall not exceed one-half the vehicle width plus 2 ft (0.6 m).

4-4.5 Air System/Air Compressor Test.

4-4.5.1 No special test facilities shall be required.

4-4.5.2 Instrumentation shall consist of the vehicle's air system pressure gauge(s), as installed by the manufacturer, and a stopwatch.

4-4.5.3 The vehicle's air system shall be fully operational for this test. The manufacturer previously shall have established the ratio of actual to required reservoir capacity and the spring brake release pressure. The test shall be conducted with the transmission in neutral and the parking brakes set.

4-4.5.4 The test shall be conducted as follows:

(a) Using the brake pedal, bleed off the air reservoir system pressure to a level below 85 psi (586 kPa) as indicated on the cab-mounted air gauge(s).

(b) Accelerate the engine to its wide-open throttle condition.

(c) When the air pressure indicator reaches 85 psi (586 kPa), start the stopwatch. If more than one air pressure indicator is installed on the vehicle, start the stopwatch when the first indicator registers 85 psi (586 kPa).

(d) Continue building air pressure with the engine at wide-open throttle until 100 psi (689.5 kPa) is registered on all air pressure indicators, stop the watch, and record the time.

(e) Using the brake pedal, bleed off the air reservoir system pressure to 0 psi (0 kPa), as indicated on the cab-mounted air gauge(s).

(f) Accelerate the engine to a wide-open throttle condition.

(g) When the wide-open throttle condition is reached, simultaneously start the stopwatch.

(h) Continue building air pressure with the engine at wide-open throttle until the previously established spring brake release pressure has been reached in the quick buildup system, stop the watch, and record the time.

4-4.5.5 The results shall be evaluated as follows:

(a) The time needed for a buildup of 85 psi to 100 psi (586 kPa to 689.5 kPa) shall be within 25 seconds or the permitted time as calculated for larger reservoir capacities.

(b) The quick buildup time shall be within 15 seconds.

4-4.6 Agent Discharge Pumping Test.

4-4.6.1 Test facilities shall consist of an open site suitable for discharging agent.

4-4.6.2 No test equipment shall be required.

4-4.6.3 The vehicle's agent system shall be fully operational for this test, and all primary hand lines shall be deployed.

4-4.6.4 The combined discharge of all nozzles shall be tested as follows:

(a) Fill both the water tank and the foam (or dyed water) tank completely with water and foam, respectively.

(b) Set the agent system to operate in the foam mode, set the system pressure for optimum performance, and engage the agent pumps. Simultaneously operate the pumps of vehicles with multiple pumps during this test.

(c) Initiate discharge first through the roof turret and then through the ground sweeps, (or optional bumper turret), primary hand lines, and undertruck nozzles until all are discharging simultaneously in a straight stream. As each nozzle is turned on, observe the range along with the system pressure.

(d) Continue to discharge until the system pressure has stabilized with all nozzles discharging.

4-4.6.5 Since measurements of actual flow rates are not practical in the field, the system shall be considered to have met the requirement in accordance with the procedures of 4-4.6.4, provided the nozzle ranges show no signs of deterioration as additional nozzles are engaged and the agent system pressure does not fluctuate by more than 10 percent where comparing the roof turret flowing by itself with the combined discharge pressure. Foam (or dyed water) shall be evident in the discharging stream from all nozzles at all times.

4-4.7 Dual Pumping System Test.

4-4.7.1 Test facilities shall consist of an open site suitable for discharging agent.

4-4.7.2 No special instrumentation shall be required for this test.

4-4.7.3 The vehicle's agent system shall be fully operational for this test.

4-4.7.4 The ability of a vehicle equipped with a dual pumping system to provide foam solution to all nozzles when only one system is active shall be tested as follows:

(a) Fill both the water tank and the foam tank completely with water, and add dye or foam concentrate to the foam tank.

(b) Set the agent system to operate in the foam mode, and set the system pressure for optimum performance.

(c) Set the primary turret(s) discharge rate in the half flow rate setting.

(d) Initiate discharge first through the primary turret(s) (at half rate) and then through the ground sweep nozzles (or alternate bumper turret), the primary hand line nozzles, and the undertruck nozzles, first with one pump operating, and then the other.

4-4.7.5 A foam or dye solution discharge stream shall be present at each nozzle tested when either pump is engaged.

4-4.8 Pump and Maneuver Test.

4-4.8.1 Test facilities shall consist of an open site suitable for discharging agent and operating the vehicle up to its maximum speed.

4-4.8.2 No test equipment shall be required.

4-4.8.3 The vehicle's agent system shall be fully operational for this test.

4-4.8.4 The positive pump and maneuver capability, along with the smooth engagement of the pump, shall be tested as follows:

(a) Fill both the water tank and the foam tank completely with water, and add dye or foam concentrate to the foam tank.

(b) With the vehicle being driven at 20 mph (32.2 km/h), engage and disengage the pump(s) without damage to the pump or pump drive system.

(c) Bring the vehicle to a stop, and prepare the primary turrets and ground sweeps (or optional bumper turret) for discharging.

(d) Place the agent selector in the foam mode, and set the agent system pressure relief to relieve at the recommended pressure for optimum performance.

(e) Initiate discharge through the primary turrets and ground sweeps/bumper turret nozzles, and drive the vehicle in a forward and reverse direction at speeds ranging up to 5 mph (8 km/h). Stop and start the vehicle, and change direction from forward to reverse while operating through this speed range without interrupting the discharge flow rate or range. Engage and disengage the pumps during the test.

(f) Repeat 4-4.8.4(e) both on and off the road.

4-4.8.5 During the test, there shall be no indication of proportioning, pressure, or flow rate instability. The operation of the pump shall not, under any conditions, cause the engine to stall. Engagement of the pump or vehicle drive shall be accomplished without introducing any unsafe vehicle dynamics such as severe lurching. Dye or foam solution shall be evident while discharging from all nozzles.

4-4.9 Hydrostatic Pressure Test.

4-4.9.1 Test facilities shall consist of an appropriate area in the vehicle manufacturer's plant.

4-4.9.2 Test equipment shall consist of the following:

(a) A hydraulic pressure gauge with a scale adequate for monitoring a pressure equal to $1^1/_2$ times the normal agent system pressure of the vehicle;

(b) A pressure charging device capable of developing a pressure equal to $1^1/_2$ times the normal agent system pressure of the vehicle and sustaining it for 15 minutes or longer;

(c) Miscellaneous plates or caps to isolate the suction side of the agent system, as necessary, from the hydrostatic test pressure.

4-4.9.3 The vehicle's agent system shall be fully assembled at the time of the test. As it is sometimes desirable to perform this test before the body is completely assembled and fire-fighting system controls are in place, the agent system shall not be required to be fully operational during the hydrostatic portion of the test.

4-4.9.4 The water and foam concentrate or foam solution discharge piping shall be tested as follows:

(a) Isolate all suction piping components that cannot tolerate the hydrostatic test pressures from the discharge piping and pump(s) by installing temporary plates or caps between these items and the discharge piping. Include the agent pumps in the test.

(b) Close all discharge nozzles, and seal any bypass lines from the pressure piping to the agent tanks.

(c) Connect a pressure charging device (e.g., electric motor-driven water pump or hand pump) into the discharge piping.

(d) Activate the pressure charging device, fill the agent pumps and discharge piping with water, and pressurize to at least $1^1/_2$ times the maximum recommended agent system operating pressure.

(e) Close the supply line from the pressure charging system, thereby sealing the discharge piping in a pressurized condition.

(f) Maintain the test pressure for at least 15 minutes without degradation.

(g) If leaks exist that cause the pressure to drop, repair the leaks and repeat the test.

(h) On completion of the hydrostatic test, disconnect the charging device and reassemble the suction piping.

(i) Fill the agent tanks and piping with water, and inspect the suction piping for leaks after the agent system has been operated in the foam mode.

4-4.9.5 No pressure decay shall be permitted during the 15-minute test, and no discharge or suction piping water leaks shall be permitted during or after agent system operation.

4-4.10 Foam Concentration Test.

4-4.10.1 Test facilities shall consist of an open site suitable for discharging agent. Access to a refill water supply and foam concentrate supply shall be required.

4-4.10.2 The test equipment described in NFPA 412, *Standard for Evaluating Aircraft Rescue and Fire Fighting Foam Equipment*, shall be used for this test.

4-4.10.3 Each discharge nozzle on the vehicle shall have been individually verified as discharging at a flow rate within the tolerance specified. The agent system shall have been verified as capable of operating at full rate.

4-4.10.4 The test shall be conducted as follows:

(a) Fill the water and foam tank to the top, and refill as necessary throughout the test.

(b) Set the foam proportioning system to proportion foams at the concentration specified, and set the agent selector for the foam mode.

(c) Set the agent system pressure relief to the recommended pressure.

(d) Engage the agent pumps and bring them up to maximum pumping speed with all discharge outlets closed.

(e) Each foam delivery system shall be tested in accordance with NFPA 412, *Standard for Evaluating Aircraft Rescue and Fire Fighting Foam Equipment*, for the individual nozzle/flow rate as follows:

1. Roof turret(s) full rate;
2. Roof turret(s) half rate;
3. Ground sweep/bumper turret;
4. Hand line nozzles;
5. Undertruck nozzles.

4-4.10.5 The foam concentrations measured shall fall within the permitted tolerances specified in NFPA 412, *Standard for Evaluating Aircraft Rescue and Fire Fighting Foam Equipment*, for each nozzle.

4-4.11 Roof Turret Flow Rate Test.

4-4.11.1 Test facilities shall consist of a level, open site suitable for discharging agent.

4-4.11.2 A stopwatch shall be required for this test.

4-4.11.3 The agent system shall be fully operational, and the agent system pressure shall be set in accordance with the manufacturer's recommendations. The water tank shall be filled completely.

4-4.11.4 The test shall be conducted as follows:

(a) Simultaneously initiate discharge through the primary turret(s) at the maximum flow rate and start the stopwatch.

(b) Continue discharging until the pump cavitates, as indicated by a significant drop in discharge pressure, and stop the watch when this occurs. Record the elapsed time.

(c) Divide the rated water tank capacity, in gallons, by the elapsed discharge time to determine the average discharge rate.

4-4.11.5 The average measured discharge rate shall be in reasonable agreement with the nominal discharge rate specified, and the total elapsed discharge time shall be no less than 1 minute nor greater than 2 minutes.

Chapter 5 Referenced Publications

5-1

The following documents or portions thereof are referenced within this standard and shall be considered part of the requirements of this document. The edition indicated for each reference is the current edition as of the date of the NFPA issuance of this document.

5-1.1 NFPA Publications.

National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.

NFPA 403, *Standard for Aircraft Rescue and Fire Fighting Services at Airports*, 1993 edition.

NFPA 412, *Standard for Evaluating Aircraft Rescue and Fire Fighting Foam Equipment*, 1993 edition.

NFPA 1901, *Standard for Pumper Fire Apparatus*, 1991 edition.

NFPA 1961, *Standard for Fire Hose*, 1992 edition.

NFPA 1963, *Standard for Fire Hose Connections*, 1993 edition.

5-1.2 Other Publications.

5-1.2.1 ANSI Publication. American National Standards Institute, 11 West 42nd Street, New York, NY 10036.

ANSI S1.4, *Specification for Sound Level Meters*, 1983.

5-1.2.2 ASME Publication. American Society of Mechanical Engineers, 345 East 47th Street, New York, NY 10017.

ASME *Boiler and Pressure Vessel Code*, 1992.

5-1.2.3 ASTM Publication. American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103.

ASTM D4956, *Standard Specification for Retroreflective Sheeting for Traffic Control*, 1994.

5-1.2.4 SAE Publications. Society of Automotive Engineers, Inc., 400 Commonwealth Drive, Warrendale, PA 15096.

SAE J551, *Standard on Performance Levels and Methods of Measurement of Electromagnetic Radiation from Vehicles and Devices (30-1000 MHz)*, 1990.

SAE J994, *Standard on Alarm-Backup-Electric Laboratory Performance Testing*, 1993.

5-1.2.5 U.S. Department of Transportation Publications. U.S. Government Printing Office, Superintendent of Documents, Mail Stop SSOP, Washington, DC 20402.

Appendix A Explanatory Material

This Appendix is not a part of the requirements of this NFPA document but is included for informational purposes only.

A-1-1.1

The basic NFPA recommendations on the use and provision of this equipment are contained in NFPA 402M, *Manual for Aircraft Rescue and Fire Fighting Operations*, and NFPA 403, *Standard for Aircraft Rescue and Fire Fighting Services at Airports*. Field testing procedures for aircraft rescue and fire-fighting vehicles utilizing foam are provided in NFPA 412, *Standard for Evaluating Aircraft Rescue and Fire Fighting Foam Equipment*. NFPA 422, *Guide for Aircraft Accident Response*, is designed, in part, to provide technical data useful in evaluating the effectiveness of these vehicles.

A-1-3 Definitions.

Approved. The National Fire Protection Association does not approve, inspect, or certify any installations, procedures, equipment, or materials; nor does it approve or evaluate testing laboratories. In determining the acceptability of installations, procedures, equipment, or materials, the authority having jurisdiction may base acceptance on compliance with NFPA or other appropriate standards. In the absence of such standards, said authority may require evidence of proper installation, procedure, or use. The authority having jurisdiction may also refer to the listings or labeling practices of an organization concerned with product evaluations that is in a position to determine compliance with appropriate standards for the current production of listed items.

Authority Having Jurisdiction. The phrase “authority having jurisdiction” is used in NFPA documents in a broad manner, since jurisdictions and approval agencies vary, as do their responsibilities. Where public safety is primary, the authority having jurisdiction may be a federal, state, local, or other regional department or individual such as a fire chief; fire marshal; chief of a fire prevention bureau, labor department, or health department; building official; electrical inspector; or others having statutory authority. For insurance purposes, an insurance inspection department, rating bureau, or other insurance company representative may be the authority having jurisdiction. In many circumstances, the property owner or his or her designated agent assumes the role of the authority having jurisdiction; at government installations, the commanding officer or departmental official may be the authority having jurisdiction.

Intended Airport Service. See also NFPA 403, *Standard for Aircraft Rescue and Fire Fighting Services at Airports*, for further information concerning aircraft rescue and fire-fighting services at airports.

Listed. The means for identifying listed equipment may vary for each organization concerned with product evaluation, some of which do not recognize equipment as listed unless it is also labeled. The authority having jurisdiction should utilize the system employed by the listing organization to identify a listed product.

A-1-4.1

A minimum 1-year warranty should be supplied by the contractor. Purchasers should require that bids be submitted with a detailed description of the vehicles offered and drawings showing general arrangements, weights, and dimensions. Data similar to that provided in the questionnaire contained in Appendix B also should be required.

A-2-2.1.2 The intent of the weight distribution requirements is to produce the most equally divided weight distribution possible across all axles and wheels. Ideally, the front axle should not be the heaviest loaded axle. It is important to realize, however, that certain customized features not covered in the major fire-fighting vehicle chapter (such as auxiliary agent systems) might necessitate that the 5-percent allowance for the front axle be exceeded. Where these situations occur, the vehicle manufacturer needs to be consulted to determine the final weight distribution and to confirm that none of the established component weight ratings is exceeded and that the brake performance of the vehicle still complies with this standard.

A-2-2.2.2 Compromise might be necessary on overall vehicle dimensions, since the dimensions selected for optimum operational performance could be in conflict with other requirements. In order to eliminate unnecessary design restrictions, specification of vehicle dimensions should be undertaken only where a particular requirement exists.

Consideration should be given to the following factors at the time of specification to determine whether vehicle dimensions should be restricted:

(a) Fire station restrictions;

(b) Access within the airport boundaries;

(c) Access outside the airport boundaries, if necessary;

(d) Requirements that affect the dimensions of local construction, if applicable;

(e) Use regulations, if applicable.

A-2-3.1.2 At higher altitudes, the performance of a vehicle can be affected due to the reduced density of the air drawn into the engine. The resulting reduction in power is more noticeable on a normally aspirated engine, (e.g., nonturbo charged).

To assess the difference in performance at higher altitudes, it is important to obtain from the manufacturer the reduced power rating of the engine at the operating altitude. From this rating, the reduced level of acceleration performance or reduced water capacity extinguishing agent can be estimated.

A-2-7.3

The mobility and handling characteristics of the vehicle greatly depend on tire selection. The tractive limit of a tire is related to the strength of the soil, power available, wheel diameter, load, number of driving wheels, tire deflection, contact area, and tread pattern.

The following guidelines are recommended:

(a) Facilities with hard, off-pavement conditions and small snow accumulations might find it desirable to wish to specify high pressure tires with small contact area to maximize high speed performance and handling.

(b) Experience has demonstrated that tires having a large diameter, a wide base, and medium pressure can provide a reasonable compromise between mobility needs and hard surface performance and handling and are suitable for many facilities where soil is not extremely soft or wet and snow accumulations are moderate.

(c) Where local conditions require high flotation, (e.g., sand, mud) mobility traction can be improved by specifying larger wheel and tire diameters, larger tire cross section, greater tire deflection, and lower wheel loads or tire pressure. Specifications result in some degradation of high speed performance and handling characteristics. Actual performance testing could be necessary to ensure the suitability of such specifications.

A-2-8

Recovery of the vehicle from adverse conditions should be made by attaching the vehicle to the axles.

A-2-9.1

It is customary for manufacturers of rescue and fire-fighting vehicles to provide a braking system based on normal commercial practice, usually connected to a recognized standard that might have legal status in worldwide territories. These standards offer certain advantages and disadvantages that can vary from one another. Operators should consider these advantages and disadvantages with respect to their particular operating conditions and legal requirements.

A-2-9.2

By preventing wheel lock-up, anti-lock braking systems (ABS) can significantly enhance driver control and vehicle stability under certain conditions. The purchaser should consider the applicability of this option.

A-2-16.3.1 Polyvinyl chloride, epoxies, and polyesters are among the acceptable classes of resins.

A-2-16.5.7 The development of the extendable turret for aviation fire protection is a recent development. As such, the design and functional requirements, as well as the tactics and procedures for its use, are not well developed. Training curricula also need to be developed. The intent of the requirements of 2-16.5.7 is to provide minimum performance criteria so that there is no degradation in the basic turret performance, while allowing individual flexibility for specific user needs. These needs can be affected by the type of aircraft being protected, the ability to access the aircraft interior, and the ability to access shielded fires.

As now envisioned, the extendable turret can be used for primary agent application as part of a first-arriving vehicle. As such, the vehicle should be capable of applying agent quickly without the need to deploy supporting outriggers. In the future, other design features or functions might be incorporated. For example, man-rated devices for use in accessing the interior cabin after fire knockdown might be incorporated. These devices might or might not require stabilizing devices; depending on the function of the vehicle, the time to deploy such devices may be permitted. In any event, there should be a maximum time for total deployment of the boom/tower device. A maximum of 30 seconds is recommended. The requirements do not prohibit the development of an advanced device or a unit with a different function, recognizing that the primary turret performance should not be compromised.

It is not recommended that agent be applied from a vertically extended position before knockdown of the exterior exposure fire, unless the fire cannot otherwise be accessed. Preliminary data from demonstrations of extendable turrets, plus data from earlier turret testing, suggest that AFFF discharged at a low level is the most effective technique. The extendable turret should be designed to extend below the roof level of the cab to take advantage of low-level AFFF application. Extension of the extendable turret below the cab level also should provide advantages in accessing shielded/obstructed areas such as wheel-well incidents and “gear down” scenarios.

To improve operator efficiency, the movement of the boom/tower should be accomplished with a single lever located within the cab. Elevation/azimuth indicators are not needed if the turret is in the line of sight of the operator.

Where specified, the extendable turret should be fitted with the appropriate tools/devices needed for a driver/operator to perform interior aircraft and tail-mounted engine fire-fighting functions remotely. These could include a skin penetrator/agent applicator for penetration of the fuselage to access interior fires from outside the aircraft. Tactics and procedures for these evolutions are not well developed and should be given careful consideration, preplanning, and training, particularly for situations where surviving passengers/crew might still be in the aircraft. Where a penetrator/agent applicator is used, a minimum flow equal to two hand lines (as specified in 2-16-6.4.3) is recommended. Airports planning to use the device for indirect attack with a skin penetrator should preplan appropriate access locations on aircraft served and the conditions under which the device is to be used.

A-2-20.2

If desired, the driver’s siren control can be wired for selective control on the steering wheel horn button. If a combination public address-type siren is desired, an electronic type having an equivalent sound output should be substituted.

A-2-21

The purchaser should specify the particular item required for the following:

(a) One ground ladder that meets the requirements of NFPA 1931, *Standard on Design of and Design Verification Tests for Fire Department Ground Ladders*;

(b) One section of hose of minimum $2^1/_2$-in. (6.4-cm) diameter for tank fill;

(c) Appropriate spanner wrenches for the fittings on the vehicle;

(d) One hydrant wrench or other wrench necessary to activate the local water supply;

(e) A SCBA meeting the requirements of NFPA 1981, *Standard on Open-Circuit Self-Contained Breathing Apparatus for Fire Fighters*, and NFPA 1500, *Standard on Fire Department Occupational Safety and Health Program*, available for each assigned fire fighter;

(f) Skin penetrator/agent applicator;

(g) Appropriate wheel chocks;

(h) 100 ft (30.5 m) of utility rope;

(i) Two axes, non-wedge type;

(j) Fire-resistant blanket;

(k) Bolt cutters, minimum 24 in. (61 cm);

(l) Multipurpose, forcible entry tool;

(m) Intrinsically safe handlight(s);

(n) Two harness cutting tools;

(o) Hook, grab, or salving tool;

(p) First aid kit;

(q) 4-lb (1.8-kg) hammer.

For a detailed discussion of rescue tools, see NFPA 402M, *Manual for Aircraft Rescue and Fire Fighting Operations*.

It is important that additional features such as structural fire-fighting equipment do not interfere with the basic ability of the vehicle to perform its primary aircraft rescue and fire-fighting function. It is considered preferable to have separate vehicles for structural fire fighting equipped with the needed complement of hose and tools, since the quantity of such equipment carried on an aircraft rescue and fire-fighting vehicle needs to be limited to conserve weight and space.

A-3-2.2.2 See A-2-2.2.2.

A-3-3.1.2 See A-2-3.1.2.

A-3-7.3

See A-2-7.3.

A-3-9.1

See A-2-9.2.

A-3-9.7

See A-2-9.2.

A-3-13.4.2.1 See A-2-16.3.1.

A-3-14.2

See A-2-20.2.

A-3-15

See A-2-21.

Appendix B Aircraft Rescue and Fire-Fighting Vehicle Questionnaire

This Appendix is not a part of the requirements of this NFPA document but is included for informational purposes only.

This questionnaire can be used to determine information on design features and requirements for aircraft rescue and fire-fighting vehicles.

Questionnaire

1. Chassis:

Make ________________ Model ____________

2. Type Drive: 4×4; 6×6; 8×8

3. Weights:

Vehicle	Front Axle (Bogie) (lb)	Rear Axle (Bogie) (lb)	Total (lb)
Empty:	________	________	________
With crew:	________	________	________
Expendable payload:	________	________	________
Total:	________	________	________
Average load per tire:	________	________	________

4. Gross Vehicle Weight Rating: ___________ lb

5. Dimensions (*See Figure B-1*):

Dimensions taken with:
Vehicle fully loaded @ _________ lb
Tire inflation pressure @ _______ lb
Overall length _________ in.; Overall width: ___________ in.;
Overall height _________ in.
Underaxle clearance: Front _________ in.; Rear ________ in.
Interaxle clearance angle ____________________ degrees
Underchassis clearance _________________ in.
Angle of: Approach ______________ degrees;
Departure ______________ degrees
Front bumper to center front wheels _______________ in.
Chassis wheel base _____________ in.
Center rear wheels to rear bumper ________________ in.

6. Engine:

Make ______________ Model ___________ Location ___________
Number of cylinders ___________
Piston displacement ____________ $in.^3$
Maximum brake
horsepower: Gross _______ @ ________ RPM
Net _______ @ ______ RPM
Maximum torque: Gross __________ @ _________ RPM
Net _______ @ ______ RPM
Governor: Make __________ Type _____________
Maximum governed speed ___________________________ RPM

7. Clutch, Fluid Coupling, Torque Converter:

Clutch: Make ________ Model _____________
Type ____________________________________
Rated Torque Capacity ______________________ lb-ft
Fluid Coupling: Make ____________ Model ______________
Rated Capacity ______________ HP
Torque converter: Make ___________ Model ______________
Stall torque ratio ___________ to 1
Rated capacity _____________ HP

8. Transmission:

Make _________ Model ______________ Type ____________
Maximum rated input torque
capacity _________________ lb-ft
Number of speeds: Forward _________________ Reverse _____________

Speed	**Gear Ratio**	**Mph* @ Engine-Governed RPM**
1	____________________	____________________
2	____________________	____________________
3	____________________	____________________
4	____________________	____________________
5	____________________	____________________
Rev.	____________________	____________________
Rev.	____________________	____________________

NOTE: If multiple range transfer case is provided, mph is to be measured with these components in high range.

9. Transfer Case:

Transfer case: Make _____________ Model _______________
Maximum rated input torque
capacity _______________ lb-ft
Gear ratio: High range ____________ Low range _________
Type drive to front and rear axles (bogie) ___________________
Center differential or compensating device:
Make ________________
Model _____________________
Type: Automatic locking

None
Driver selective locking
Direct drive:
Type: Connected at all times
Driver selective disconnect

10. Front Drive:

Axle
Bogie
Make ________ Model __________ Gear ratio __________ to 1
Type drive: Single reduction
Double reduction
If double reduction, type final reduction:
Spur gears at differential
Internal gears at hubs
Steering drive ends: Make _________ Model ____________
Type: Constant velocity
Cardan
Differential or compensating device:
Make __________________ Model ________________
Type: Automatic locking
Driver selective type
Nonlocking
Maximum rated input torque capacity ____________ lb-ft
Maximum rated load on tires at ground ___________ lb
Axle tread _________ in.; Bogie wheel base ___________ in.

11. Rear Drive:

Axle
Bogie
Make __________ Model __________ Gear ratio __________ to 1
Type drive: Single reduction
Double reduction
If double reduction, type final reduction:
Spur gears at differential
Internal gears at hubs
Differential or compensating device:
Make _________________ Model ___________________
Type: Automatic locking
Driver selective type
Nonlocking
Maximum rated input torque capacity ____________ lb-ft
Maximum rated load on tires at ground ___________ lb

Axle tread ____________ in.; Bogie wheel base ____________ in.

12. Suspension:

	Front	Rear
Suspension, type		
Leaf spring	_____	_____
Coil spring	_____	_____
Torsion bar	_____	_____
Air cushion	_____	_____
Diagonally opposite wheel motion	_____	_____
Axle motion before bottoming from level loaded position	_____	_____
Shock absorbers	_____	_____

Unsprung weight at full load ___________ percent

13. Wheels, Tires, and Rims:

	Front	Rear
Configuration		
Singles	_____	_____
Duals	_____	_____
Wheels, type		
Disc	_____	_____
Spoke	_____	_____
Wheels, construction		
Steel	_____	_____
Aluminum	_____	_____
Rims, type		
Single piece	_____	_____
Multiple piece	_____	_____

Rim size (in.)

Load/ply rating _____ _____

Maximum load (lb) _____ _____

Inflation pressure (psi) _____ _____

Tire, type

Bias ply _____ _____

Radial _____ _____

Tube _____ _____

Tubeless _____ _____

Tire tread design __________

14. Electrical System:

Voltage: Lighting _______________ Starting ___________
Alternator: Make __________ Model _________ Voltage ____________
Capacity rating at engine-governed speed ___________________________
Capacity rating at 50 percent engine-governed
speed ____
Batteries: Make ___________ Model __________ Number ____________
Capacity, each _________________ amp-hr @ 20-hr
Rate, each cold-cranking amp @ 0°F (-17.8°C)
Starter: Make ____________________ Model _________________________
On-board auxiliary battery charger
On-board auxiliary compressor ________________________ volts
External battery charging connection ___________________ volts
Engine coolant preheating connection ___________________ volts
Electrical system radio suppressed

15. Fuel System:

Fuel Pumps: Mechanical, number ____________________
Electrical, number __________________________
Fuel tank capacity ____________ gal; Location ______________________

16. Exhaust System:

Muffler
Construction of system ____________________
Location of exhaust discharge ________________

17. Air System:

Compressor capacity _______________ cfm
Air reservoir capacity _______________ in.^{3}
Quick buildup time ______________________________
Air dryer: Make _______________ Model ____________________

18. Service Brakes:

Make ____________________ Number ______________________
Front, type: Internal shoe
Disc
Braking area ____________ in.^{2}
Brake application system:
Make ______________________________
Type: Air-mechanical
Hydraulic, with:
Air booster
Vacuum booster
No booster
Stopping distance from 20 mph (32.2 km/h) _______________________
Stopping distance from 40 mph (64.4 km/h) ________________________

19. Emergency Brakes:

Make _____________ Location ______________________________
Braking area ________________ in.^{2}
Type: Entirely independent of service brakes
Connected to service brakes
Stopping distance from 40 mph (64.4 km/h) ________________________

20. Steering:

Steering gear: Make ______________ Model _____________________
Power assist: Make _______________ Model _____________________
Wall-to-wall turning diameter ____________ ft

21. Body:

Construction:
Chassis rigid, unitized
Chassis flexible
Frame material ____
Body construction material _____________________________________
Location of steps or ladders to working deck:
Each side
Rear
Type nonskid surface on steps, walkways __________________________

22. Cab:

Location _______________ Number of seats ______________________
Number of doors ______________ Type glass ______________________
Driver visibility: Horizontal _____________ Vertical _________________
Turret access hatch ___________
Insulation thickness/R value ______________
Cab construction material ________________
Instrument panel:
 Hinged
 Circuit quick disconnects
 Panel lighting
 Removable
 Instrument backlighting
Cab volume __________________ ft^3
Heater capacity _______________ Btu
Air conditioning capacity _______ Btu

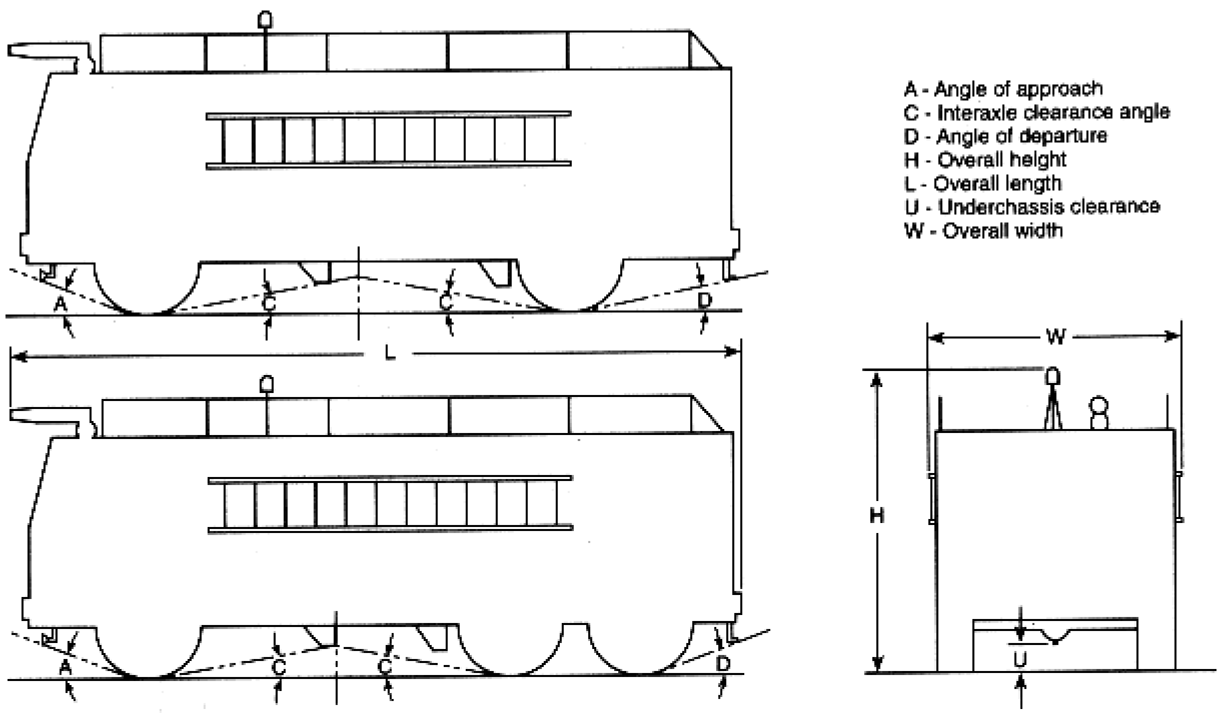


Figure B-1 Vehicle dimensions.

23. Pump(s) and Pump Drive:

Number of water pumps _________ Material _______________
Total pump capacity __________ gpm at _______ psi
Total pump drive:

Separate engine(s)
Power takeoff
If separate engine(s) drive:
Engine make _______________ Model _________________
Location _____________ Number cylinders ______________
Piston displacement ________________ $in.^3$
Maximum brake horsepower:
Gross _________ @ _________ RPM
Voltage of ignition and starting system ____________________
Type clutch, if furnished _____________
If power takeoff drive:
Location of P.T.O.:
Engine
Power divider
Torque converter
Transmission
Is power transmission uninterrupted? ______________
P.T.O. clutch type ____________
Torque capacity ______________ lb-ft
Clutch actuation ______________
Maximum engine speed at which P.T.O. can be engaged ___________ RPM
Suction piping material ______________________________________
Suction system low-point drain:
Type valve _________ Size ____________ in.
Pump discharge gates:
Number __________ Size ____________ in.; Location ___________
Pump check valve(s):
Number __________ Size ____________ in.; Location ____________
Type pressure relief device ________________
Discharge piping material ________________
Type valves ________________ Type couplings ________________
Churn line: Design __________________ Location
Open system
Closed system
Churn line valve control method ________________

24. Types and Quantities of Extinguishing Agents (Totals):

Carbon dioxide: Low pressure _____________ lb;
High pressure __________ lb
Dry chemical ____________ lb; Type dry chemical __________________
Halon ________________ lb; Type halon ________________________
Foam liquid concentrate ______________ gal;
Type concentrate ________________
[Specify if protein, fluoroprotein, or aqueous-film-forming foam

(AFFF)]
Water ____________________ gal

25. Water Tank:

Location ________ ; Usable capacity __________ gal;
No. of tanks __________
Dimensions: Height __________ in.; Length _________ in.;
Width _________ in.
Height of tank bottom above ground _____________ in.
Construction material _______________
Interior coating: Yes ___________ No ________
Coating material _____________
Baffles:
Number transverse ______________
Number longitudinal _______________
Anti-swirl: Yes _________ No __________
Top fill opening: Size _________ in.;
Number ____________ ; Type _______________
Side fill connections: Size ____________ in.; Number ____________;
Thread type _________________ ; Location ______________

26. Foam-Liquid Concentrate Tank(s):

Location _______________ Number __________________
Usable capacity (total) _________________ gal
Type: Rigid construction material ______________________
Flexible
Top fill size ____________ No. of can openers _____________
Side fill connections: Size _________ in.; Number ____________;
Thread type ______________ ; Location _________________

27. Foam Pumping and Proportioning System:

Type foam proportioning system ____________________________
Foam-liquid concentrate percentage:
Variable from ________ to _______________ percent
Foam-liquid concentrate pump: Material _________________
Capacity _______________ gpm at _____________ psi
Type pump drive __________________
Foam-liquid concentrate piping: Material __________________

28. Roof Turret Foam Nozzle(s):

Number ____________ Make ____________ Model _____________
Location __________________ Type nozzle _____________________
Single discharge
Dual discharge

Turret flow rate(s) ______________ gpm;
Operating pressure _____________ psi
Discharge: Foam-straight stream
Foam-variable pattern
Water-straight stream
Water-spray
Range-straight stream, foam
Far point ________________ ft;
Near point _______________ ft
Range-fully dispersed or spray, foam
Full width _________________ ft; Far point _________________ ft;
Near point _________________ ft
Turret control: Manual only
Power assist
Full power
Foam quality: Expansion rate __________________ to 1
25-percent drainage time _________________ min

29. Hand Line(s) Water/Foam:

Number __________ Location ___________________________
Length hose per reel ______________ ft; Size _______________
Reel mounting: Fixed
Swing-out
Height of reel top above ground ______________ in.
Nozzle: Make _____________ Model ________________
Liquid flow rate _____________ gpm
Foam quality: Expansion ratio __________ to 1
25-percent drainage time ___________ min
Foam pattern: Width ___________ ft; Range ____________ ft

30. Ground Sweep Nozzle(s):

Number ____________________ Location __________________
Liquid flow rate(s) __________________________ gpm
Foam quality: Expansion ratio _____________ to 1
25-percent drainage time __________ min
Foam pattern: Width ___________ ft; Range ____________ ft
Control locations: In cab
Outside

31. Bumper Turret Nozzle(s):

Number ___________ Make ___________ Model ______________
Location _____________ Type Nozzle _________________________
Single discharge
Dual discharge

Turret Flow Rate(s) __________ gpm;
Operating pressure __________ psi
Discharge: Foam-straight stream
Foam-variable pattern
Water-straight stream
Water-spray
Range-straight stream, foam
Far point _________ ft; Near point ___________ ft
Range-fully dispersed or spray, foam
Full width ___________ ft; Far point __________ ft;
Near point ____________ ft
Turret control: Manual only
Power assist
Full power
Foam quality: Expansion rate ________________ to 1
25-percent drainage time ____________ min

32. Undertruck Nozzle(s):

Number _______________________ Location ___________________
Liquid flow rate(s) ______________________ gpm
Control locations: In cab
Outside

33. Emergency Warning Devices:

Flashing beacon: Make ______________ Model _________________
Location ______________________
Siren: Make ______________ Model ________ Location ___________
Control location _________________
Horn: Air
Electric
Reverse alarm: Make _________________ Model ____________________

34. Auxiliary Agent Nozzle(s):

Turret: Type ____
Number _______________________ Location _________________________
Make _________________________ Model ___________________________
Range _____________ ft
Discharge rate ___________________ lb/sec
Hand line: Type ____
Number _______________________ Location __________________________
Length hose per reel __________ ft
Size ________________ in.
Reel mounting: Fixed
Swing-out

Height of reel top above ground ____________ in.
Nozzle:
Make _______________ Model _________________
Range _________________ ft
Discharge rate ______________ lb/sec

Appendix C Driver's Enhanced Vision System: A Technical Approach for Aircraft Rescue and Fire-Fighting Services

This Appendix is not a part of the requirements of this NFPA document but is included for informational purposes only.

C-1 Introduction.

Several accidents have occurred in poor visibility conditions, and, with the proliferation of category IIIC landing systems, more requirements for fire fighting in low visibility conditions can be expected. Aircraft rescue and fire-fighting services currently have no reliable way to locate and navigate to crash sites at airports under conditions of poor visibility.

C-2 Background.

Aircraft rescue and fire-fighting services are required to demonstrate an ability to respond anywhere on the airport operational runway areas as part of earning their annual certificate. This response requirement is considered vital to the ability of ARFF services to gain control of a rapidly growing external post-crash fuel fire and their ability to protect the evacuating passengers from the aircraft fuselage. A response in 3 minutes is dependent on the vehicles' ability to accelerate rapidly from the rescue services facilities and to maintain approximately a 50-mph (80.5-km/h) approach to the accident site. Accomplishing this task under substandard visibility conditions such as fog and rain prevents the responding vehicles from reaching this speed.

There is a clear need to provide operational equipment in the rescue vehicles that maintains their response ability if low visibility flight operations are to be conducted.

The problem of poor visibility response at airports for rescue and fire-fighting services can be broken down into three components:

(a) Locating the accident sites;

(b) Navigating aircraft rescue and fire-fighting vehicles to crash sites;

(c) Negotiating terrain and obstacles in low visibility conditions.

Airport fire services need a driver's enhanced vision system (DEVS) that addresses these three components.

Aircraft rescue and fire-fighting services need to obtain an accurate position fix on the crash site within a time parameter that is comparable to their response time (under 3 minutes). The current system for locating crash sites that are not visible to aircraft rescue and fire-fighting services relies on visual observations, estimates, and verbal descriptions of airport landmarks provided by air traffic controllers. This system is prone to human error. The optimal solution to this problem is a system that locates a crash site on a digital map of the airport automatically and transmits this location to aircraft rescue and fire-fighting services.

Navigation of aircraft rescue and fire-fighting vehicles to crash sites is an issue that can be solved with today's technology. Sophisticated radio navigation systems such as the global positioning system (GPS) provide precise positioning capability. This position information, combined with digital maps of the airport area, can be displayed on a geographic map or heads-up display (HUD) to guide the crews.

Negotiating terrain and locating obstacles in low visibility conditions is an important capability that aircraft rescue and fire-fighting services currently do not possess. The only aids that rescue services currently use for improving vision under poor visibility conditions are windshield wipers and headlights. These devices often do not improve visibility enough to allow rescue teams to drive safely at the high speeds necessary to reach a crash site within a reasonable time. One aid that would provide improvement is a forward looking infrared device (FLIR). FLIRs currently are used by the military to improve visibility at night and during severe weather conditions. The FLIR system needs to be fully functional as soon as the fire equipment departs the fire station facility. Exit time typically is under 30 seconds from the time of accident notification. On-line and operational equipment should in no way impede the ability of the aircraft rescue and fire-fighting services to respond. Equipment is to be automated and is to necessitate little attention by the truck operator.

C-3 General Requirements.

A driver's enhanced vision system (DEVS) is required in an aircraft rescue and fire-fighting vehicle for airport emergency equipment. It facilitates faster and safer travel to emergency situations at night and in adverse weather conditions. It provides a substantial increase in the ability to locate people, other aircraft, vehicles, and debris at the emergency site. Its ability to allow the driver to see through flames, smoke, and fog during both the day and night provides ARFF vehicles with a significant increase in effectiveness in every phase of emergency operations.

The DEVS requires a transparent window display (TWD), which is often called a heads-up display (HUD), combined with a global positioning system (GPS) and geographic information system (GIS), on-board sensors, a central data and command RF link (radio communications), and a forward looking infrared (FLIR) sensor. These elements are to be integrated into a single functional system. A validation demonstration program is necessary to provide the quantitative information needed to justify the DEVS and refine it for the ARFF services application.

C-4 Operating Scenarios and Capabilities.

Mission Description

From the moment that an alert is received until the end of the emergency, the ARFF services mission is subject to stress and uncertainty. At any given moment, day or night, the equipment needs to be fully functional within a few seconds, regardless of adverse weather. Often vehicles and aircraft are positioned on the runways and taxiways in unusual or unexpected locations. In the event of an aircraft accident, victims and debris can be present anywhere on the airport. At the same time, the large size of modern airports, with multiple parallel runways and taxiways, places a priority on the ability to travel at high speed to the emergency site.

Once the ARFF services have arrived at the location, the ability to assess the situation is crucial to carrying out the mission. The information available to the vehicle operator contributes directly to the level of performance of the ARFF mission. This information needs to be obtained without any increase in the workload. The DEVS reduces the impact of night conditions, adverse weather, fire, and smoke so that the operator's performance approaches that achieved during the optimum daylight scenario.

To achieve this goal, information is to be provided in an easily recognizable form, without the need for vehicle operator intervention. Rescue vehicle location, the location of the emergency, the location of other vehicles (ground and aircraft), the location of people, and the location of debris are the basic data needed (and normally available during the least difficult situations). The condition of the aircraft, location of victims, presence and location of spilled burning fuel, and location of other ARFF personnel also are crucial. In addition, the possible presence of toxic gases caused by spilled or burning cargo needs to be determined to provide for a safe response to the situation. Finally, since multiple vehicles and ARFF crews are always involved in most emergency situations, a centralized command and control system is needed to coordinate the activities of all elements of the emergency response team. The DEVS is one element of this command and control system.

C-5 Required Capabilities.

The DEVS provides an increase in the knowledge available to the emergency crew. The crew are able to see through fog, rain, sleet, and snow. The crew are able to see through smoke and flames in and around the burning aircraft, to detect the position of evacuees and trapped passengers, and to distinguish among the debris to move into a position for fire fighting. They are able to apply extinguishing agents to the hottest areas of the burning fire more precisely. They also can track other fire fighters through the smoke and fire while rescue efforts are under way.

The FLIR device provides the ARFF operator with the ability to detect debris and other vehicles (stationary or moving) in the vicinity, as well as to detect passengers evacuating from the aircraft. The FLIR detector can electrocute humans in a smoke or fog environment where normal vision is inadequate. The FLIR stores information for normal driving conditions. The FLIR uses the brighter-than-background standard runway and taxiway lights, which are detected as it travels to the site.

C-6 System Elements.

The elements of the DEVS for the ARFF vehicle demonstration include a forward looking infrared device (FLIR), a transparent window display (TWD) or heads-up display (HUD), and a global positioning system (GPS) with geographic information system (GIS) or mapping.

C-7 Forward Looking Infrared Device.

The FLIR is a high resolution infrared detector. It is enhanced with wide dynamic range processing for increased penetration of smoke and fog. The FLIR contains a two-dimensional focal plane array using platinum silicide as the detector material. It operates at wavelengths from 8 micrometers to 12 micrometers and has a sensitivity of 32.2°F (0.1°C). An alternate FLIR of 3 micrometers to 5 micrometers with similar sensitivity also is implemented to establish whether the shorter wavelength provides significant benefits in the smoke environment. A key element in the use of the FLIR device for this application includes a total hands-off automation philosophy.

Rapid cool-down is another function dictated by the nature of FLIR detectors. To achieve the best performance, these detectors need to be cooled to very low temperatures [in the range of -454°F (–270.2°C)]. The cooling systems that have been developed have an operating life of about 2500 hours. Rapid cool-down or extended standby life cycle is considered essential to an ARFF application. Zero (0) or near-zero time start-up is an operational requirement for effectiveness.

C-8 Dynamic Range Issues.

To detect people and debris, the FLIR has a sensitivity of approximately 32.2°F (0.1°C). At the same time, the FLIR can be expected to deliver this sensitivity in the presence of flames that reach temperatures of 1832°F (1000°C). In order to accomplish this, the FLIR operates over an instantaneous dynamic range of about 10,000: 1.

C-9 Transparent Window Display.

The transparent window display system hardware consists of a projector, an optical element, and a symbol generator to provide information to an operational position. The symbol generator provides data to the projector by means of dedicated signal cables. The symbol generator has the capability to receive and to process data links from up to six video inputs and two serial inputs while formatting messages based on a control program. The control program uses the data's priority, refresh rate, and other site-specific criteria to implement the sequence and content of the information presentation.

C-10 Projector.

The DEVS projector is a high-brightness CRT, monochrome emitter that creates and projects a focused image onto the window of the ARFF vehicle. The projector is designed to be placed 60 in. to 72 in. (152.4 cm to 182.9 cm) from the window. There are optional mounting schemes that allow the projector to be mounted off-axis from the window to accommodate existing mechanical obstructions. The projector is to be equipped to accept standard signal inputs that include RS-170 to utilize the TWD as a simple replacement of an existing heads-down display (HDD).

C-11 Optical Element.

The optical element is mounted to the window of the ARFF vehicle to act as a dynamic display surface within the truck cab. The optical element should be 6 in.^{2} to 12 in.^{2} (38.7 cm^2 to 77.4 cm^2) and affixed to a selected location on the window with room temperature vulcanizing material. The location is to be predefined to reflect data in a uniform manner that is specified by both lateral and vertical angles perpendicular to the plane of the window. The viewing zone should offer a lateral reflection angle of 30 degrees and a vertical reflection angle of 15 degrees. The information is to be presented in a bright green color and is to be focused at the plane of the window. The DEVS is not to obstruct the view to the outside of the vehicle.

C-12 Symbol Generator.

The symbol generator is to be a microcomputer-based system designed for rack mounting in an equipment bay. This remote computer offers the capability to interface directly with a selected set of on-board data channels or discrete indicator inputs and is linked with a GPS tracker and a FLIR. The symbol generator is programmed with the mission-specific control scheme and operates in an automatic mode. There is a keyboard and monitor option that supports on-site changes of the data communications and control routines. The symbol generator formats data "pages" and routes this information to the appropriate projector based on priority or currency or on demand. The symbol generator is capable of being configured to accept a variety of standard signal inputs including RS-232, RS-422, and RS-170.

C-13 Global Positioning System.

A global positioning system (GPS) receiver is to be mounted on the ARFF vehicle and interfaced with the transparent window display system for display of position information. The GPS is to be a six-channel receiver capable of tracking up to eight satellites. The GPS receiver calculates new position data once every second. Position accuracy is specified at a maximum of 82 ft (25 m), with a typical accuracy of about 32.8 ft to 49.2 ft (10 m to 15 m). An additional ground-based differential transmitter on the airfield provides accuracy from 3.3 ft to 9.8 ft (1 m to 3 m).

C-14 Geographic Information System.

The airport mapping system by which the ARFF vehicle is navigated may be permitted to be developed by several methods. One method being considered is the digital reconstructive method. This is accomplished by taking an aerial photo- graph of the airport and digitizing it so it then can be displayed on the computer screen for mapping. This method, as it is developed, might provide the increased local terrain and hazards definition needed by the ARFF vehicle to travel on and around the airfield. Additional mapping capability with definitions of 1 mi, 3 mi, and 10 mi (1.6 m, 4.8 m, and 16.1 m) provide for call-up mapping in the event of an accident off the airport operational areas. Digital aerial mapping is an emerging technology that provides three-dimensional hazard definition of streams, swales, and drainage culverts, as well as other hazards that could impede the progress of the rescue.

C-15 Computer Information Enhancements.

Once an operational computer is placed in the ARFF vehicle, it provides a host of other fire-fighting capabilities. Fire fighters are able to have the complete airport emergency plan available in the computer with menu-driven software. Toxic and hazardous material indexes can be provided. Complete instructions on emergency door and entryway door operations for every type of commercial aircraft can be provided.

C-16 Vehicle Electrical Upgrade.

Because of the need for better power sources, vehicles with new technology equipment need to undergo some modifications to the existing electrical systems. Computers and electronically controlled devices need smooth-filtered and stable voltage sources. The equipment targeted for installation is modified to operate in the voltage ranges used on the existing vehicles. This usually is 12-volt or 24-volt DC. Special power converters and voltage stabilizers are to be considered. There also are requirements for the addition of 115-volt AC in some cases. Operating off portable generator power sources that might already exist on some of these vehicles does not, in most cases, provide, the smooth, stabilized power sources of these requirements. Transformer rectifiers and power converters do not provide a major challenge for the technological requirements of this program. Low-cost portable battery back-up systems also should be considered to provide power for start-up of the vehicle as well as accidental shutoff of the vehicle system supply. The cost for these required voltage sources is minimal when compared to the trouble-free environment that they provide for the electronic boards and computer systems.

C-17 Final Assessment.

The object of this assessment program is to provide information about the new computer-based equipment and vision enhancement devices that help the airport rescue services perform their assigned mission under suboptimal visibility conditions. The cost of installing this equipment can be justified by the need to operate aircraft under these poor visibility conditions. If operations are conducted that allow the aircraft to take off and land under poor visibility conditions, it is reasonable to expect that additional requirements for fire-fighting response under low visibility conditions will be established.

The technology needed to perform the driver's enhanced vision system (DEVS) is available now. Although the equipment can be bought off the shelf, installation necessitates some additional research effort because aircraft rescue and fire-fighting mission requirements were not considered in the research efforts that produced this technology. In each case, the individual elements of the DEVS considered the fact that the proposed system should require low operational workload by the operator. Each piece of the system endeavors to use current technological equipment with some hardware and software modifications. Finally, the DEVS should be designed for easy installation and a maintenance-free duty life cycle or at the least a modular rack installation design allowing the removal and replacement of components by current maintenance personnel without adding to the personnel burden of a rescue and fire-fighting service.

The most important issue is cost. Historically, this technology is expensive. Some of the reasons for these high costs were dictated by low production runs and the survivability conditions for which the equipment originally was designed. Equipment meeting the rigorous requirements necessary for military applications can add many thousands of dollars to the final purchase price. It is hoped that, with the careful redesign and unique adaptation of existing equipment designs and unit cost price decreases, the cost of using this technology in an aircraft rescue fire-fighting vehicle can be reduced substantially in the near future.

C-18 Driver's Enhanced Vision System Guidelines.

C-18.1 DEVS Performance Characteristics.

The driver's enhanced vision system (DEVS) is an integrated system of sensors, computers, and navigational equipment designed to improve the response and operation of ARFF crews in low visibility conditions. The DEVS consists of three components: a night or low visibility capability, a vehicle navigation capability, and a vehicle tracking capability, which are integrated using a digital radio data link.

To meet the DEVS requirements, systems need to integrate all three components cohesively. Each component should be integrated into the vehicle's normal operations through a systematic approach of understanding and adapting the technology to the needs of the fire-fighting population.

In the sections that follow, the base performance characteristics are detailed. It is important to note that technology development in the enhanced vision area is progressing rapidly; therefore, the criteria that follows should be considered minimal. Questions regarding specific production systems, new performance capabilities, or recommended systems should be directed to the

FAA's airports office.

C-18.2 Low Visibility Capability.

The intent of the low visibility capability is to provide an enhanced picture of the environmental scene through the use of a chamber or other sensor system displayed inside of the cab. For the immediate future, it appears that forward looking infrared (FLIR) technology holds the most promise for aiding visibility in smoke, fog, and haze and at night. The minimum recommended performance characteristics of the low visibility system are provided below:

(a) **General.**

Expected worst case visibility	0 ft range/0 ft ceiling
Time to operational	≤30 seconds
Detection of humans	500 ft (152.4 m), temp: –20°F to 115°F (28.9°C to 46.1°C), moving 55 mph (88.5 km/h), clear conditions
	500 ft (152.4 m), temp: –20°F to 115°F (28.9°C to 46.1°C), moving 50 mph (80.5 km/h), light fog conditions
	400 ft (121.9 m), temp: –20°F to 115°F (28.9°C to 46.1°C), moving 40 mph (64.4 km/h), heavy fog conditions
	400 ft (121.9 m), temp: –20°F to 115°F (28.9°C to 46.1°C), moving 40 mph (64.4 km/h), smoke conditions
	300 ft (91.4 m), temp: –20°F to 115°F (28.9°C to 46.1°C), moving 35 mph (56.3 km/h), rain/snow conditions
Detection of GA aircraft	2500 ft (762.0 m), temp: –20°F to 115°F (28.9°C to 46.1°C), moving 55 mph (88.5 km/h), clear conditions
	1000 ft (304.8 m), temp: –20°F to 115°F (28.9°C to 46.1°C), moving 50 mph (80.5 km/h), light fog conditions
	500 ft (152.4 m), temp: –20°F to 115°F (28.9°C to 46.1°C), moving 40 mph (64.4 km/h), heavy fog conditions
	500 ft (152.4 m), temp: –20°F to 115°F (28.9°C to 46.1°C), moving 40 mph (64.4 km/h), smoke conditions

	500 ft (152.4 m), temp: –20°F to 115°F (28.9°C to 46.1°C), moving 35 mph (56.3 km/h), rain/snow conditions
Detection of objects near fires	People, debris, wreckage, and equipment within 20 ft (6.1 m) of a 6-ft (1.8-m) diameter Jet A fuel fire from a range of 1000 ft (304.8 m)

(b) **FLIR Specific.**

IR waveband	Long wave IR energy (8µm to 12 µm)
Video output	RS-170 or industry standard video
Gain and level controls	Automatic
Horizontal field of view	≥28 degrees (40 degrees preferred)
Vertical field of view	>20 degrees, aspect ratio to match vertical
Lens clearing capability	Windshield wiper, high pressure air, or equivalent
Temp. and humidity changes	Changes in ambient temperature and humidity should not result in condensation inside the FLIR housing or optics assembly
Mounting	On top of vehicle with pan and tilt capability, remote-control equipped, line of sight aligned with driver's line of sight
Video monitor	8-in. to 10-in. (6.2-cm to 25.4-cm) diagonal display mounted near driver's line of sight
	Alternative: Heads-up display with field-of-view to match FLIR

C-18.3 Navigation Capability.

The intent of the navigation capability is to allow for accurate positioning of the vehicle on or around the airport surface. The navigation capability should provide a depiction of the vehicle, notable landmarks, roadways, and other guidance aids. Information should be provided to the driver in a meaningful form appropriate to the needs of the fire response.

The navigation capability consists of three main components: a global positioning system (GPS) receiver, a computer system containing supporting maps and navigation information, and a display/control system for driver information.

For full capability on the airport, the DEVS should incorporate both capabilities into the design. The performance characteristics of the components in the above list are as follows:

Position availability	Computed position within 30 sec/hr/day, 7 days/week
Accuracy	Two-dimensional position within 15 ft (4.6 m)
Dead reckoning	Coasting capability when satellite track is lost due to shadowing
Position update rate	< 1/sec
Initialization and operation	Fully automatic
Map — levels of detail	Level 1 – Airport operations area
	Level 2 – Airport property boundary
	Level 3 – 5-mile (8-km) radius of the airport center; either variable or fixed zooms within each level should be provided
Map — orientation	North-up or heading-up, selectable (Note: Heading-up orientation is required for situational awareness in low visibility conditions and unfamiliar areas)
Map — visual orientation cues	Vehicle orientation, vehicle heading, direction of low visibility coverage
Driving cues	Range/bearing indicator in line-of-sight (on FLIR display or separate)
Data link — error checking	Standard error checking
Data link — frequency selection	Selectable to airport location
Display — color	≥ 256 colors

C-18.4 Tracking Capability.

The tracking capability components include: Differential GPS (DGPS) correction software, data link hardware/software, and an integrated display/control system for command center operations. The command center can be either fixed or mobile, depending on individual airport ARFF operations. This capability is intrinsically tied to the tracking capability, which allows for the monitoring of the positions of other vehicles, the crash site, identified victims, and other factors, as well as linkage to a centralized display for emergency coordination.

Map — orientation	North-up with dynamic zoom and pan
Data link — error checking	Standard error checking
Data link — frequency selection	Selectable to airport location
Display — color	Large high-resolution monitor [>19-in. (>48.3-cm) diagonal color monitor, 1280 × 1024 resolution

C-19 Glossary of Technical Terms

Aircraft Rescue and Fire-Fighting (ARFF). Formerly known in the fire-fighting industry as crash, fire, and rescue.

Cool-down in the Operational Environment of an Infrared Detector. Term used to describe the period of time needed for the refrigeration unit of the optical sensor to cool the unit to approximately –454°F (–270.2°C) below zero (0). This cool-down mode provides the necessary sensitivity of 10,000: 1 for infrared thermal detection.

Driver's Enhanced Vision System (DEVS). A vision enhancement system utilizing several electronic and computer-based components that aids in improving sight as well as movement or navigation around the airport during reduced visibility operational conditions.

Forward Looking Infrared (FLIR). A heat detector device that allows the viewer to see radiant heat projected from objects. These devices work in the micron band of the infrared spectrum (e.g., 8 µm to 12 µm).

Geographic Information System (GIS). A device that allows an aerial map of the airport to be displayed with markers that move along the image as the vehicle changes position.

Global Positioning System (GPS). A device that picks up signals from orbiting satellites and determines positions of location on earth by reference to longitude and latitude.

Heads-Up Display (HUD). The military name for a device that allows a person to look and operate a device while viewing through the cockpit window of an aircraft. This device displays information.

Transparent Window Display (TWD). An electronic device that projects an image on a special coated glass or plastic that also allows the viewer to see through the clearplate with a slight reduction in visibility.

Appendix D Vehicle Summary

This Appendix is not a part of the requirements of this NFPA document but is included for informational purposes only.

Performance Parameter For Fully Loaded Vehicle	Combined Agent				Major Vehicle Class						
	1	2	3	4	1	2	3	4	5	6	7
1. Water tank (gal): Minimum usable capacity	≥ 100	≥ 200	≥ 300	≥ 500	≥ 1000	≥ 1500	≥ 2500	≥ 3000	≥ 4000	≥ 5000	≥ 6000
2. Side slope stability (degrees):	30			28	30	28	26.5	24			
Percent grade:	58			53	58	53	50	45			
3. Dynamic balance (mpg): Minimum speed on a 100-ft (30.5-m) radius circle	25				22		18.5				
4. Angle of approach (degrees):	30										
5. Angle of departure (degrees):	30										
6. Interaxle clearance (degrees):	12										
7. Underbody clearance (in.):	13			18	18						
8. Underaxle clearance at differential housing bowl (in.):	8			10.5	13						
9. Wall-to-wall turning diameter:	≤ three times the vehicle's length										
10. Maximum acceleration time from 0 mph to 50 mph (0 km/h to 80.5 km/h) (sec):	25	30			23	26	35	40	45	50	
11. Top speed (mph):	≥ 65										
12. Service brake:											
Stopping distance at 20 mph (32.2 km/h) (ft):	≤35							≤ 40			
40 mph (64.4 km/h) (ft):	≤ 131							≤ 160			
Percent grade holding of fully loaded vehicle:											
Ascending:	≥ 50										
Descending:	≥ 50										
13. Emergency brake stopping distance at 40 mph (64.4 km/h) (ft):	≤ 288										
14. Percent grade holding for the parking brake:											
Ascending:	≥ 20										
Descending:	≥ 20										

Continued on next page

Appendix D Vehicle Summary (cont.)

Performance Parameter Agent System	Combined Agent				Major Vehicle Class						
	1	2	3	4	1	2	3	4	5	6	7
1. Water tank (gal): minimum usable capacity	≥ 100	≥ 200	≥ 300	≥ 500	≥ 1000	≥ 1500	≥ 2500	≥ 3000	≥ 4000	≥ 5000	≥ 6000
Percent of deliverable water											
On level ground	100										
On 20% side slope	85				75						
On 30% ascending/descending grade	85				75						
2. Primary turret(s) discharge					Total flow rate can be a combination of a roof turret or extendable turret and a bumper turret						
Total flow rate (gpm): + 10%/-0% or	N/A	150	200	250	750	750	1250				
Individual flow rate of the roof turret if used in combination with a bumper turret (gpm): + 10%/–0%	N/A				500	500	1000				
Stream pattern/distances											
Straight/far point (ft):	N/A	≥ 125			≥ 160	≥ 190	≥ 230	≥ 250			
Dispersed/far point (ft):	N/A	≥ 25			≥ 60	≥ 65	≥ 70	≥ 75			
Dispersed/width (ft):	N/A	> 20	≥ 25		≥ 35						
3. Extendable waterway											
Individual flow rate of the extendable turret if used in combination with a bumper turret (gpm): + 10%/–0%	N/A				500	500	1000				
Stream pattern/distances											
Straight/far point (ft):	N/A				≥ 160	≥ 190	≥ 230	≥ 250			
Dispersed/far point (ft):	N/A				≥ 60	≥ 65	≥ 70	≥ 75			
Dispersed/width (ft):	N/A				≥ 35						
4. Bumper turret	N/A	May be permitted to be used as the roof turret									
Flow rate (gpm): + 10%/–0%	N/A	150	250								
Straight stream distance (ft):	N/A	≥ 150									
Flat pattern distances:											
Far point (ft):	N/A	≥ 50									
Width (ft):	N/A	≥ 20				≥ 30					
Near point (ft):	N/A	≥ Within 30 ft of front bumper									
5. Ground sweep											
Flow rate (gpm): + 10%/–0%	N/A				≥ 100 to ≤ 300						
Flat pattern distances:											
Far point (ft):	N/A				≥ 30						
Width (ft):	N/A				≥ 12						
6. Number of water/foam hand lines needed per vehicle (select from below):	1				2						
7. Woven jacket water/foam hand line											
Nozzle flow rate (gpm): + 10%/–0%	95										
Straight stream distance (ft):	≥ 65										
Dispersed stream pattern:											
Range (ft):	≥ 20										
Width (ft):	≥ 15										
Hose inside diameter (in.):	≥ 1.50										
Hose length (ft):	≥ 150										
8. Reeled water/foam hand line											
Nozzle flow rate (gpm): + 10%/–0%	60										
Straight stream distance (ft):	≥ 50										
Dispersed stream pattern:											
Range (ft):	≥ 20										
Width (ft):	≥ 15										
Hose inside diameter (in.):	≥ 1.00										
Hose length (ft):	≥ 100										

Continued next page

Performance Parameter Agent System	Combined Agent				Major Vehicle Class						
	1	2	3	4	1	2	3	4	5	6	7
9. Auxiliary agent	Required				Where specified						
Capacity, if required (lb):	≥ 500				≥ 500 where specified						
10. Dry chemical hand line	Required				Where specified						
Discharge rate:	≥ 5 lb/sec to ≤ 7 lb/sec(≥ 2.3 kg/sec to ≤ 3.3 kg/sec)										
Range (ft):	≥ 25										
Hose inside diameter (in.):	≥ 1.00										
Hose length (ft):	≥ 100										
11. Dry chemical twinned turret	N/A	Required			Where specified						
Discharge rate:		≥ 16 lb/sec to ≤ 22 lb/sec (≥ 7.3 kg/sec to ≤ 10 kg/sec)									
Range (lt):		≥ 100									
Width (ft):		≥ 17									
12. Halon hand line (1211 or replacement)											
Discharge rate:	≥ 5 lb/sec to ≤ 7 lb/sec (≥ 2.3 kg/sec to ≤ 3.3 kg/sec)										
Range (ft):	≥ 25										
Hose inside diameter (in.):	≥ 1.00										
Hose length (ft):	≥ 100										

Appendix E Referenced Publications

E-1

The following documents or portions thereof are referenced within this standard for informational purposes only and thus are not considered part of the requirements of this document. The edition indicated for each reference is the current edition as of the date of the NFPA issuance of this document.

E-1.1 NFPA Publications.

National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.

NFPA 402M, *Manual for Aircraft Rescue and Fire Fighting Operations*, 1991 edition.

NFPA 403, *Standard for Aircraft Rescue and Fire Fighting Services at Airports*, 1993 edition.

NFPA 412, *Standard for Evaluating Aircraft Rescue and Fire Fighting Foam Equipment*, 1993 edition.

NFPA 422, *Guide for Aircraft Accident Response*, 1994 edition.

NFPA 1500, *Standard on Fire Department Occupational Safety and Health Program*, 1992 edition.

NFPA 1931, *Standard on Design of and Design Verification Tests for Fire Department Ground Ladders*, 1994 edition.

NFPA 1981, *Standard on Open-Circuit Self-Contained Breathing Apparatus for Fire Fighters*,

1992 edition.

NFPA 415

1997 Edition

Standard on Airport Terminal Buildings, Fueling Ramp Drainage, and Loading Walkways

1997 Edition

This edition of NFPA 415, *Standard on Airport Terminal Buildings, Fueling Ramp Drainage, and Loading Walkways*, was prepared by the Technical Committee on Airport Facilities and acted on by the National Fire Protection Association, Inc., at its Fall Meeting held November 18-20, 1996, in Nashville, TN. It was issued by the Standards Council on January 17, 1997, with an effective date of February 7, 1997, and supersedes all previous editions.

This edition of NFPA 415 was approved as an American National Standard on February 7, 1997.

Origin and Development of NFPA 415

NFPA 415, *Standard on Aircraft Fueling Ramp Drainage*, was first adopted in 1961. Subsequent editions were published in 1966, 1973, 1977, 1983, 1987, and 1992.

NFPA 416, *Standard on Construction and Protection of Airport Terminal Buildings*, was first adopted in 1962. Subsequent editions were published in 1967, 1972, 1973, 1975, 1983, 1987, and 1993.

NFPA 417, *Standard on Construction and Protection of Aircraft Loading Walkways*, was first adopted in 1963. Subsequent editions were published in 1968, 1973, 1977, 1985, and 1990.

The 1997 edition of NFPA 415 is a combination of the above three documents and has a new title, *Standard on Airport Terminal Buildings, Fueling Ramp Drainage, and Loading Walkways*.

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Alternates

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(Alt. to D. C. Kennedy)

Joseph A. Behnke, Ansul Inc., WI [M]
(Alt. to D. Toupalik)

Delbert R. Chase, Jr., Federal Express Corp., TN [U]
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Jeffrey W. DeLong, Industrial Risk Insurers, CA [I]
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(Alt. to J. D. Dick)

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(Voting Alt. to J&H Rep.)

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(Alt. to D. J. Burkhart)

Al Mazur, Transport Canada - Airports Group, ON [E]
(Voting Alt. to TC-AG Rep.)

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(Alt. to L. M. Krasner)

Jack Poole, Poole Fire Protection Engr, Inc., KS [SE]
(Alt. to S. C. Dryden)

V. G. Pyrpyris, Port Authority of NY & NJ, NY [E]
(Alt. to A. Rhome)

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(Alt. to D. Rice)

Terry L. Victor, Grinnel Fire Protection Systems Co., MD [M]
(Alt. to C. J. Marsolo)

Nonvoting

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(Member Emeritus)

Jerome Lederer, CA
(Member Emeritus)

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This list represents the membership at the time the Committee was balloted on the text of this edition. Since that time, changes in the membership may have occurred. A key to classifications is found at the front of the book.

NOTE: Membership on a committee shall not in and of itself constitute an endorsement of the Association or any document developed by the committee on which the member serves.

Committee Scope: This Committee shall have primary responsibility for documents on fire safety for the construction and protection at airport facilities involving construction engineering but excluding airport fixed fueling systems.

NFPA 415

Standard on Airport Terminal Buildings, Fueling Ramp Drainage, and Loading Walkways

1997 Edition

NOTICE: An asterisk (*) following the number or letter designating a paragraph indicates that explanatory material on the paragraph can be found in Appendix A.
Information on referenced publications can be found in Chapter 5 and Appendix B.

Chapter 1 Administration

1-1 Scope.

This standard specifies the minimum fire protection requirements for the construction and protection of airport terminal buildings. It specifies the minimum requirements for the design and maintenance of the drainage system of an aircraft fueling ramp to control the flow of fuel that can be spilled on a ramp and to minimize the resulting possible danger. In addition, it contains the minimum requirements for the design, construction, and fire protection of aircraft loading walkways between the terminal building and aircraft.

1-2* Purpose.

The purpose of this standard is to provide a reasonable degree of protection for life and property from fire at airport terminal complexes.

Requirements applicable to ramp drainage systems are intended to limit the fire hazard from fuel spillage by the following:

(a) Controlling the spread of a fuel spill to limit exposure to buildings, aircraft loading walkways, concourses, or elevated structures in order to prevent the fuel's liquid or vapors from reaching a source of ignition or accumulating within structures

(b) Limiting the spread of the fuel spill over the ramp surface and preventing the transmission of vapors by the drainage system from exposing aircraft or other equipment parked or operating on the ramp

The purpose of this standard is also to specify minimum criteria for fire protection of aircraft loading walkways that can serve as an egress route from an aircraft in the event of a flammable liquid spill fire on the airport ramp exposing the walkway and the aircraft.

1-3 Applicability.

It is not intended that the provisions of this document be applied to facilities, equipment, structures, or installations that were existing or approved for construction or installation prior to the effective date of the document, except in those cases where it is determined by the authority having jurisdiction that the existing situation involves a distinct hazard to life or adjacent property.

1-4 Definitions.

For the purpose of this standard, terms shall be defined as follows:

Aircraft Fueling Ramp. Any outdoor area at an airport, including aprons and hardstands, where aircraft are normally fueled or defueled.

Aircraft Loading Walkway. An aboveground device through which passengers move between a point in an airport terminal building and an aircraft. Included in this category are walkways that are essentially fixed and permanently placed, or walkways that are essentially mobile in nature and that fold, telescope, or pivot from a fixed point at the airport terminal building.

Airport Ramp. Any outdoor area, including aprons and hardstands, where aircraft can be positioned, stored, serviced, or maintained, irrespective of the nature of the surface of the area.

Airport Terminal Building.* A structure used primarily for air passenger enplaning or deplaning, including ticket sales, flight information, baggage handling, and other necessary functions in connection with air transport operations. This term includes any extensions and satellite buildings used for passenger handling or aircraft flight service functions. Aircraft loading walkways and "mobile lounges" are excluded.

Approved.* Acceptable to the authority having jurisdiction.

Authority Having Jurisdiction.* The organization, office, or individual responsible for approving equipment, an installation, or a procedure.

Listed.* Equipment, materials, or services included in a list published by an organization that is acceptable to the authority having jurisdiction and concerned with evaluation of products or services, that maintains periodic inspection of production of listed equipment or materials or periodic evaluation of services, and whose listing states that either the equipment, material, or service meets identified standards or has been tested and found suitable for a specified purpose.

Potential Fuel Spill Points. The points on or around the aircraft or airport ramp where fuel can be released. These points include fueling hydrants, fuel servicing vehicles, fuel tank fill connections, fuel vent openings, and fuel dump valves.

Satellite. A structure that can be adjacent to but separated from the airport terminal building, accessible aboveground or through subway passages, and used to provide flight service operations, such as passenger check-in, waiting rooms, food service, enplaning or deplaning, etc.

Shall. Indicates a mandatory requirement.

Should. Indicates a recommendation or that which is advised but not required.

Chapter 2 Airport Terminal Buildings

2-1 General.

2-1.1*

Airport terminal buildings shall be of Type I, Type II, or Type IV construction, as defined in NFPA 220, *Standard on Types of Building Construction.*

2-1.2*

Interior finish shall be limited to that permitted in Class A places of assembly as specified in NFPA *101*□, *Life Safety Code*□.

2-1.3

Aircraft fueling facilities and ramps shall be designed in accordance with NFPA 407, *Standard for Aircraft Fuel Servicing*, and Chapter 3 of this standard.

2-1.4

Belowgrade areas or blind spaces in airport terminal buildings shall be protected against flammable fuel or vapor penetration or shall be mechanically ventilated to provide at least four complete air changes per hour. The mechanical ventilation system shall be installed in accordance with Chapters 2 and 3 of NFPA 91, *Standard for Exhaust Systems for Air Conveying of Materials*.

2-1.5*

Where potential fuel spill points are located less than 100 ft (30.5 m) horizontally from glazing material covered openings in airport terminal building walls facing the airport ramp, they shall be provided with an automatically activated water spray system or an automatically activated, listed fire shutter as follows:

(a) An automatically activated water spray system installed in accordance with NFPA 15, *Standard for Water Spray Fixed Systems for Fire Protection.*

1. The system shall be designed to provide a density of at least 0.25 gpm/ft^2 [10.2 (L/min)/m^2] over the exterior surface area of the glazing material.

2. Where multiple water spray systems are used, the water supply shall be capable of supplying all systems that could be expected to operate as a result of one fire incident.

3. The detection system design analysis shall include consideration of false alarms and detector response time.

(b) An automatically activated, listed fire shutter installed in accordance with its listing.

Exception No. 1: Openings covered with glazing material that have the lowest part of the glazing material not less than 7 ft (2.1 m) above the finished floor level.

Exception No. 2: Openings covered with glazing material listed for use in a fire barrier and installed in accordance with the listing.

2-2 Heating, Ventilating, and Air Conditioning.

2-2.1

Heating, ventilating, and air conditioning systems shall be installed in accordance with NFPA 31, *Standard for the Installation of Oil-Burning Equipment;* NFPA 54, *National Fuel Gas Code;* and NFPA 90A, *Standard for the Installation of Air Conditioning and Ventilating Systems,* as applicable.

2-2.2*

Air supply intake and exhaust openings for air conditioning or ventilating equipment serving the terminal building, if located on the ramp side, shall be not less than 10 ft (3 m) above the grade level of the ramp and shall be at least 50 ft (15.2 m) from any point of flammable vapor release.

2-2.3*

Openings to rooms containing coal-, gas-, or oil-fired equipment, or any rooms containing any other open flame device, that face the ramp side of the terminal shall be above ramp grade and 50 ft (15.2 m) from any point of flammable vapor release.

2-2.4

Stacks or chimneys from a boiler, heater, or incinerator shall terminate at least 20 ft (6.1 m) above ramp grade and above the roof of the building. Stacks or chimneys from boilers or heaters using solid fuel or from any incinerator shall be fitted with double screening to control fly ash and sparks. Such stacks or chimneys shall be located so the outlet is at least 100 ft (30.5 m) horizontally from any aircraft position or point of flammable vapor release.

2-2.5

Incinerators shall conform to the requirements of Chapter 2 of NFPA 82, *Standard on Incinerators and Waste and Linen Handling Systems and Equipment.*

2-2.6

Exhaust hood ventilation systems for restaurant and flight kitchens shall conform to the applicable portions of NFPA 96, *Standard for Ventilation Control and Fire Protection of Commercial Cooking Operations.*

2-3 Exits.

2-3.1

Airport terminal building means of egress shall conform to the requirements of NFPA *101, Life Safety Code.*

2-3.2*

Exits that discharge onto an airport ramp and are provided solely for the purpose of meeting emergency egress requirements from public areas shall be placarded "Emergency Exit Only" in letters at least 2 in. (4.9 cm) high.

2-4 Electrical.

2-4.1

All electrical installations shall be in accordance with NFPA 70, *National Electrical Code*¨.

2-4.2

Ventilation and access openings for transformer or electrical service rooms or vaults located on the ramp side of an airport terminal building shall be located as outlined in 2-2.2.

2-5 Fire Protection.

2-5.1* Sprinkler Systems.

The airport terminal building shall be provided with an automatic sprinkler system installed in accordance with NFPA 13, *Standard for the Installation of Sprinkler Systems*.

Exception: Terminal buildings with less than 12,000 ft^2 (1115 m^2) total floor area for the assembly portion of the occupancy.

2-5.1.1 Passenger handling areas shall be classified as Ordinary Hazard Group 1 Occupancy, as defined in NFPA 13, *Standard for the Installation of Sprinkler Systems*, for the purpose of sprinkler system design.

2-5.1.2* Other areas of the airport terminal building shall be classified in accordance with 1-4.7 of NFPA 13, *Standard for the Installation of Sprinkler Systems*, based on the occupancy of the area.

2-5.1.3 Covered Plane-Loading Positions. Airport terminal buildings having canopy areas or roofed-over recesses at aircraft loading positions that, in effect, place the aircraft totally or substantially under such canopies or roofs shall have these canopies or roofs protected by automatic sprinkler systems in accordance with NFPA 409, *Standard on Aircraft Hangars.*

2-5.2 Fire Alarm and Communications Systems.

A fire alarm and communications system shall be installed as required by 8-3.4 of NFPA *101, Life Safety Code.*

2-5.2.1 Means to alert the public fire department or the airport fire station shall be available through manual fire alarm pull stations. Manual fire alarm services shall be installed in accordance with NFPA 72, *National Fire Alarm Code.*

2-5.2.2* Annunciation for all building fire alarm signals shall be provided near the front entrance of the building.

Exception: This annunciation shall not be required if the public fire department has two-way voice communication with a constantly attended location.

2-5.3 Fire Hydrants.

Fire hydrants shall be provided on both the ramp and street sides of airport terminal buildings. Such hydrants shall be located so that no portion of the terminal building is more than 500 ft (152.4 m) from a hydrant.

2-5.4 Standpipe and Hose Systems.

Standpipe and hose systems shall be provided for all airport terminal buildings in excess of two stories [35 ft (10.7 m)] in height or 100 ft (30.5 m) in shortest horizontal dimension. Standpipe and hose systems shall be installed in accordance with NFPA 14, *Standard for the Installation of Standpipe and Hose Systems.*

2-5.4.1 Class I standpipe systems shall be provided in buildings protected throughout by an approved automatic sprinkler system. Each $2^1/_2$-in. (63.5 mm) hose connection shall be equipped with a $2^1/_2$-in. × $1^1/_2$-in. (63.5-mm × 38.2-mm) reducer and cap.

2-5.4.2 Class III standpipe systems shall be provided in nonsprinklered buildings. The exceptions in NFPA 14, *Standard for the Installation of Standpipe and Hose Systems,* for Class III systems shall be applicable to this requirement.

2-5.5 Water Supply.

Water supply from public or private sources shall be adequate to supply maximum calculated sprinkler demand plus a minimum of 500 gpm (1893 L/min) for hose streams. The supply shall be available at the rate specified for a period of at least 1 hour.

2-5.5.1* Main sizes shall be hydraulically calculated based on the total domestic and fire protection requirements. Mains shall be not less than 8 in. (20 cm) in diameter except that laterals shall be permitted to be 6 in. (15 cm) in diameter if not over 200 ft (61 m) long.

2-5.5.2* Hydrants shall be readily accessible to fire-fighting vehicles traveling on surfaces adequate for supporting such vehicles.

2-5.5.2.1 Hydrants shall be listed.

2-5.5.2.2 Hydrants shall be located or protected to prevent mechanical or vehicular damage, including taxiing aircraft.

2-5.5.2.3 Hydrants recessed into the ground shall have identifiers in the pavement to assist in their prompt location at night and by personnel who might not be familiar with the location of the hydrants.

2-5.5.3* Water supply systems shall be regularly tested to ensure operation.

2-5.6 Portable Fire Extinguishers.

Portable fire extinguishers shall be provided throughout the airport terminal building in accordance with NFPA 10, *Standard for Portable Fire Extinguishers.*

Chapter 3 Aircraft Fueling Ramp Drainage

3-1 Aircraft Fueling Ramp Slope and Drain Design.

3-1.1*

Aircraft fueling ramps shall slope away from terminal buildings, aircraft hangars, aircraft loading walkways, or other structures, with a minimum grade of 1 percent (1:100) for the first 50 ft (15.2 m). Beyond this distance, the ramp slope to drainage inlets shall be permitted to be reduced to a minimum of 0.5 percent (1:200).

3-1.2*

Aircraft fueling ramp drainage as specified herein shall be accomplished by the provisions of 3-1.1 in conjunction with the following:

(a) The use of drain inlets with connected piping

(b) The use of open-grate trenches

3-1.3

Drainage inlets, where provided, shall be located a minimum of 50 ft (15.2 m) from structures outlined in 3-1.1.

3-1.4

The drainage system of any aircraft fueling ramp shall be so designed that the fuel or its vapor cannot enter into the drainage system of buildings, areas utilized for automobile parking, public or private streets, or the public side of airport terminal or aircraft hangar structures. In no case shall the design allow fuel to collect on the aircraft fueling ramp or adjacent ground surfaces where it could constitute a fire hazard.

3-1.5

The final separator or interceptor for the entire airport drainage system shall be designed to allow disposal of combustible or flammable liquids into a safely located, approved containment facility.

3-1.6

Grates and drain covers shall be removable to facilitate cleaning and flushing.

3-1.7*

If open-grate drainage trenches are used as a collection means, such open trenches, including branches, shall not be over 125 ft (38.1 m) in length with a minimum interval of 6 ft (1.8 m) between open-trench sections to act as fire stops. Each 125-ft (38.1-m) section shall be individually drained through underground piping. Open trenches shall not be used where they are in the line of pedestrian or passenger traffic.

3-1.8

Underground piping and components used in drainage systems shall be noncombustible and inert to fuel.

3-2 Drain and Separator Maintenance.

3-2.1*

Periodic maintenance checks shall be conducted of all ramp drainage systems and interceptors to ensure that they are clear of obstructions and function properly.

3-2.2

Large volume flushing with water shall be conducted through appropriate drainage elements to purge the residual fuel from these drainage elements after any large fuel spill on the aircraft fueling ramp enters the drainage system.

Chapter 4 Aircraft Loading Walkways

4-1 Basic Design.

4-1.1

Each aircraft loading walkway installation shall be designed to provide a safe means of egress from the aircraft for a period of five minutes under fire exposure conditions equivalent to a free-burning jet fuel spill fire.

4-1.2

Protection of the aircraft loading walkway shall be accomplished by one of the following methods:

(a) Construction design meeting the requirements of Sections 4-1, 4-2, 4-3, and 4-4

(b) Fixed fire protection meeting the requirements of Sections 4-1, 4-2, and 4-5 of this chapter

4-2 Requirements for All Aircraft Loading Walkways.

4-2.1*

Interior finish other than textiles of walls and ceilings and walkways shall be Class A as defined in 6-5.2.3 of NFPA *101*, *Life Safety Code*, and classified in accordance with NFPA 255, *Standard on Method of Tests of Surface Burning Characteristics of Building Materials.*

4-2.2

Interior textile finish of walls and ceilings in walkways shall be as limited by 6-5.2.3.5 of NFPA *101*, *Life Safety Code.*

4-2.3

Interior floor finish in walkways shall be Class I as defined in 6-5.4 of NFPA *101*, *Life Safety Code*, and classified in accordance with NFPA 253, *Standard Method of Test for Critical Radiant Flux of Floor Covering Systems Using a Radiant Heat Energy Source.*

4-2.4

There shall be no windows other than those located in the ramp access service door and in the cab area for the purpose of operating the aircraft loading walkway.

4-2.5*

During a ramp fire emergency, walkway interiors shall have a positive air pressure delivered from a source that shall remain uncontaminated.

4-2.6*

Any source of negative air pressure in the aircraft loading walkway shall be automatically shut down in the event of a fire emergency.

4-2.7

Any door in the egress path through the loading walkway to the terminal building shall swing in the direction of egress from the aircraft towards the terminal building and shall be equipped with panic hardware on the aircraft side.

4-2.8 Cab and Rotunda Slat Curtains.

4-2.8.1 Cab slat curtains and rotunda slat curtains shall meet the requirements of 4-4.8 by one of the following methods:

(a) Intrinsic structural features

(b) Fire-resistive coatings

(c) Automatically activated water cooling systems in accordance with 4-5.2

(d) Automatically activated fire curtains

(e) A local application of a foam system_in accordance with 4-5.3 under the cab and rotunda that is automatically activated and covers an area extending 15 ft (4.6 m) beyond the perimeter of the cab and rotunda. This shall supersede the 10-ft criteria of 4-5.3.

Exception: When the rotunda is located more than 50 ft (16 m) from the fuel fill or fuel vent point of aircraft and the rotunda slot curtain is of noncombustible construction.

4-3 Materials.

4-3.1

Exterior surfaces of floor, roof, walls, and load-bearing structural members shall be constructed entirely of materials or composite assemblies that maintain the structural integrity and heat transfer characteristics needed to meet the requirements specified in 4-1.1 and Section 4-4.

4-3.2

Flexible closures, canopies, wipers, and weather-sealing devices shall be subjected to the accelerated weathering procedures specified in Section 8-6 of NFPA 701, *Standard Methods of Fire Tests for Flame-Resistant Textiles and Films*, after which they shall meet the requirements of 4-4.7 or 4-4.10 of this standard, as applicable.

4-3.3

The manufacturer shall provide, in writing, the anticipated service life expectancy of components that contribute to fire safety.

4-4 Fire Tests.

4-4.1 Scope of Fire Tests.

4-4.1.1 Tests shall be conducted to establish the performance of materials and methods of construction, and to verify their structural integrity and heat transfer characteristics so as to satisfy the five-minute exit route criteria specified in 4-1.1.

4-4.1.2 The test methods specified in this chapter shall be applicable to assemblies of units and to composite assemblies of structural materials for aircraft loading walkways, including walls, girders, beams, slabs, and composite slab and beam assemblies for floor and walls either tested individually as floor or wall panels or as a complete assembly. Also, they shall be applicable to other assemblies and structural units that constitute permanent integral parts of a finished aircraft loading walkway.

4-4.1.3 The condition of acceptance for tests specified in this section for aircraft loading walkways shall be documented by one of the following methods. Such submittals shall be subject to acceptance by the authority having jurisdiction.

(a) Tests shall be conducted in accordance with the requirements and procedures of Section 4-4.

(b) Evidence of compliance shall be permitted to be achieved by other methods such as modeling, calculation, or testing. The submitter must show that the method used proves that components achieve a level of fire safety at least equal to that produced by the procedure in Section 4-4.

4-4.1.4 The tests shall register performance during the required period of exposure and shall not be construed as having determined suitability for use after fire exposure.

4-4.2 Time-Temperature Curve to Be Used.

The conduct of fire tests of materials and construction shall be controlled by the time-temperature curves in Figure 4-4.2 and Table 4-4.2.

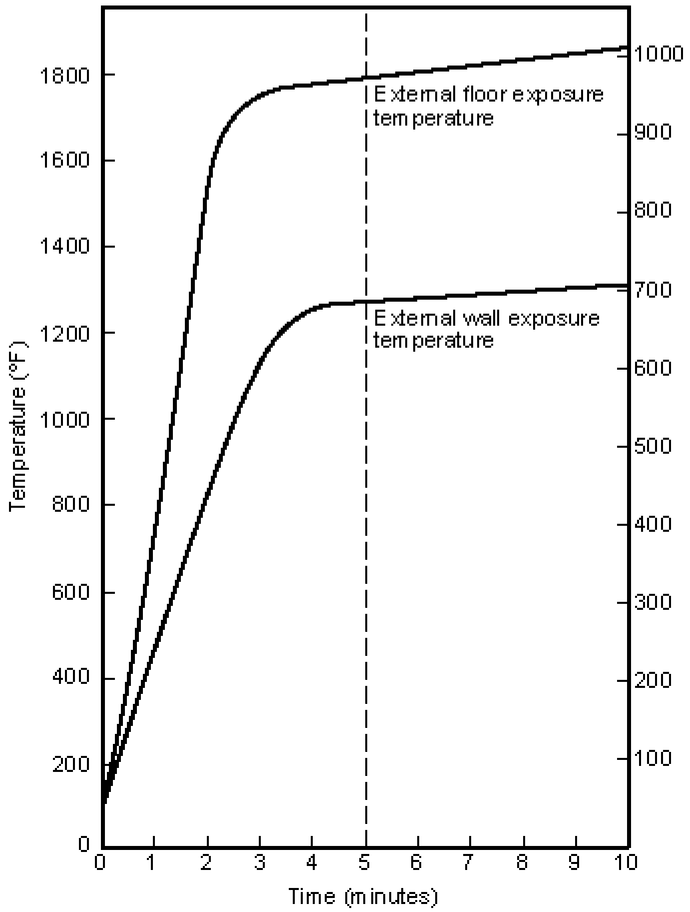


Figure 4-4.2 Typical furnace time-temperature curves for fire testing of aircraft loading walkways. (*See Table 4-4.2.*)

Table 4-4.2
Typical Furnace Time-Temperature Gradients for Fire Testing of Aircraft Loading Walkways
(See Figure 4-4.2.)

	Exposed Floor Sections		Exposed Wall Sections	
Time	**Temperature**		**Temperature**	
Min:Sec	**ºC**	**ºF**	**ºC**	**ºF**
0:00	20	68	20	68
0:20	160	320	90	194
0:40	300	572	165	329
1:00	440	824	235	455

1:20	580	1076	310	590
1:40	720	1328	380	716
2:00	860	1580	450	842
2:20	915	1679	520	968
2:40	940	1724	595	1103
3:00	955	1751	635	1175
3:20	960	1760	660	1220
3:40	965	1769	675	1247
4:00	970	1778	685	1265
4:20	970	1778	690	1274
4:40	975	1787	690	1274
5:00	975	1787	690	1274
5:20	975	1787	695	1283
5:40	980	1796	695	1283
6:00	980	1796	695	1283
6:20	985	1805	700	1292
6:40	985	1805	700	1292
7:00	990	1814	700	1292
7:20	990	1814	705	1301
7:40	995	1823	705	1301
8:00	995	1823	705	1301
8:20	995	1823	710	1310
8:40	1000	1832	710	1310
9:00	1000	1832	710	1310
9:20	1005	1841	715	1319
9:40	1005	1841	715	1319
10:00	1005	1841	715	1319

4-4.3 Furnace Temperatures.

4-4.3.1 The temperature fixed by the curve shall be deemed to be the average temperature obtained from the readings of not less than nine thermocouples for a floor or wall section. The thermocouples shall be symmetrically located and distributed to show the temperature near all parts of the sample and shall be partially enclosed in porcelain tubes $^3/_4$ in. (19 mm) in outside diameter and $^1/_8$ in. (3 mm) in wall thickness with a minimum exposed length of thermocouple wires of $1^1/_2$ in. (38 mm). The exposed length of the pyrometer tube and thermocouples in the furnace chamber shall be not less than 12 in. (305 mm). Other types of thermocouples or pyrometers that under test conditions give the same indications as those specified herein within the limit of accuracy that applies for real-time furnace temperature measurements shall be permitted to be used.

4-4.3.1.1 For floor sections, the junction of the thermocouples shall be placed 12 in. (305 mm) away from the exposed surface of the sample at the beginning of the test and during the test shall not touch the sample as a result of its deflection.

4-4.3.1.2 For walls, the thermocouples shall be placed 6 in. (152 mm) away from the exposed face of the sample at the beginning of the test and shall not touch the sample during the test as a result of its deflection.

4-4.3.2 The temperatures shall be measured and reported at intervals not exceeding 15 seconds.

4-4.3.3 The accuracy of the furnace control shall be such that at any given time the temperature obtained by averaging the results from the pyrometer readings shall not be less than 90 percent of the temperature curve shown in Figure 4-4.2.

4-4.4 Temperatures of Unexposed Surfaces of Floors and Walls.

4-4.4.1 Temperatures of unexposed surfaces shall be measured with exposed-type thermocouples placed under felted refractory fiber pads.

4-4.4.1.1 The refractory fiber pads shall be of flexible, felted material, free of organic additives, and they shall exhibit the following properties:

(a) Length and width shall be 6 ± $^1/_8$ in. (152 ± 3.18 mm).

(b) Thickness shall be 0.375 ± 0.063 in. (9.5 ± 1.6 mm).

(c) Dry weight shall be 0.147 ± 0.053 lb (67 ± 24 g).

(d) Thermal conductivity [at 150°F (66°C)] shall be 0.37 ± 0.03 Btu in./h ft^2·°F (0.053 ± 0.004 W/m·K).

(e) Hardness indentation on soft face shall be 0.075 ± 0.025 in. (1.9 ± 0.6 mm). Indentation shall be determined in accordance with ASTM Test Method C569. Modified Brinnell values of hardness are obtained by the following relationship:

$$\text{hardness} = 2.24 / y$$

where y = the measured indentation in inches

(f) The pads shall be shaped by wetting, forming, and drying to constant weight to provide complete contact on sharply contoured surfaces.

4-4.4.1.2 The thickness measurement shall be made under the light load of a $^1/_2$-in. (13-mm) diameter pad of a dial micrometer gauge.

4-4.4.1.3 The wire leads of the thermocouple shall have an immersion under the pad and shall be in contact with the unexposed surface for not less than $1^1/_2$ in. (38 mm). The hot junction of the thermocouple shall be placed approximately under the center of the pad. The outside diameter of protecting or insulating tubes shall be not more than $^5/_{16}$ in. (8 mm). The pad shall be held firmly against the surface, and shall fit closely about the thermocouples. The wires from the thermocouple in the length covered by the pad shall be not heavier than No. 18 B & S gauge 0.04 in. (1.02 mm) and shall be electrically insulated with heat-resistant and moisture-resistant coatings.

4-4.4.2 Temperature readings shall be taken at not less than nine points on the surface. Five of these shall be symmetrically located: one to be approximately at the center of the walkway specimen and four to be approximately at the center of its quarter sections. The other four shall be located at the discretion of the testing authority to obtain representative information on the performance of the walkway specimen under test. None of the thermocouples shall be located nearer to the edges of the test specimen than one and one-half times the thickness of the construction, or 12 in. (305 mm). Thermocouples shall not be located opposite or on top of beams, girders, or other structural members.

4-4.4.3 Temperature readings shall be taken at intervals not exceeding 15 seconds.

4-4.4.4 Where the conditions of acceptance place a limitation on the temperature of the unexposed surface, the temperature end point of the fire-endurance period shall be determined by the average of the measurements taken at individual points. If a temperature rise of 30 percent in excess of the specified limit occurs at any one of these points, the remainder shall be ignored and the fire-endurance period judged as ended.

4-4.5 Test Specimen.

4-4.5.1 The test specimen shall be representative of the construction for the classification desired in regard to materials, workmanship, and details such as dimensions of parts and shall be built under conditions representative of actual aircraft loading walkway construction and operation. The physical properties of the materials and ingredients used in the test specimen shall be determined and recorded.

4-4.5.2 The test specimen shall be protected during and after fabrication in order to ensure normality of its quality and condition at the time of the test. The ambient air temperature at the beginning of the test shall be within the range of 50ºF to 90ºF (10ºC to 32ºC). The velocity of air across the unexposed surface of the sample, measured just before the test begins, shall not exceed 4.4 ft/sec (1.3 m/s), as determined by an anemometer placed at right angles to the unexposed surface. If mechanical ventilation is employed during the test, an air stream shall not be directed across the surface of the specimen.

4-4.5.3* The fire-endurance test shall be continued on the specimen with its applied load, if any, until failure occurs, or until the specimen has withstood the test conditions for a period of 10 minutes.

4-4.5.4 Results shall be reported in accordance with the performance in the tests prescribed in these methods. Time-temperature results shall be reported at 15-second intervals. Reports shall include observations of significant details of the behavior of the material or construction during the test and after the furnace fire is cut off, including information on deformation, spalling, cracking, burning of the specimen or its component parts, continuance of flaming, and production of smoke.

4-4.6 Tests of Walls and Floors.

4-4.6.1 The dimensions of the sample to be tested shall be determined based upon the construction features of the specific walkway being tested. The dimensions selected shall ensure that the sample, when tested, will demonstrate the ability of the most critical elements of the walkway to withstand stress concentrations without failure and without separations that would permit fire and smoke intrusion. Verification documentation supporting the selection of the dimensions shall be approved by the authority having jurisdiction.

4-4.6.2 The effect of exposure to elevated temperatures of working stress seen as worst case load combinations during actual usage shall be accomplished by one of the following two methods:

(a) A superimposed load to the specimen shall be applied in a manner calculated to develop theoretically the design-allowable stresses contemplated by the design during the test described in 4-4.2.

(b) The yield strength of the structural medium shall be correlated to the maximum temperature recorded in 4-4.2. Structural submittals shall be made using this new yield strength showing nonfailure conditions have been met.

Worst-case load combinations shall be derived from the following:

(a) Floor Live Load:	40 lb/ft^2 (195 kg/m^2)
(b) Roof Load:	25 lb/ft^2 (122 kg/m^2)
(c) Wind Load:	2.5 lb/ft^2 (61 kg/m^2)

4-4.6.3 The test shall be successful when the following conditions of acceptance are met:

(a) The wall or floor section shall have sustained the applied load during the fire-endurance test without passage of flame for a minimum period of five minutes. Flaming shall not appear on the unexposed face.

(b) The maximum allowable surface temperature of the cool side of a wall or floor section shall not exceed 250ºF (121ºC) during a five-minute exposure as determined by 4-4.4.4.

4-4.7 Tests of Flexible Closures.

4-4.7.1 The test specimen area exposed to the test fire shall not be less than 2 ft × 2 ft (0.62 m × 0.62 m) square. The test specimen shall be representative of all elements of the flexible closure, including framework assembly and mechanisms for attachment to the aircraft loading walkway.

4-4.7.2 The test shall be successful when all of the following conditions of acceptance are met:

(a) The test specimen shall have withstood the fire-endurance test as defined by the time-temperature curve for external walkway wall exposure in Figure 4-4.2 without passage of flame for a minimum period of five minutes.

(b) The closure material also shall pass the following test, designed to measure the radiant heat flux to which a human can be subjected while exiting an aircraft under a fuel spill fire emergency condition. A specimen of the closure material that reproduces the most expanded actual field operating configuration, regarding folds and pleats, existing 6 ft (1.8 m) above the floor shall be tested in a furnace. The furnace temperature applied to the exposed exterior surface of the closure material shall be raised in accordance with the time-temperature curve for external walkway wall exposure in Figure 4-4.2. Measurements shall be taken by a radiometer positioned between a minimum distance of 39.4 in. (1 m) and a maximum distance of 78.7 in. (2 m) away from the cool side surface of the test specimen. The radiometer shall have a view angle small enough such that it "sees" only the test specimen and not the frame or furnace wall. The approximate equivalent human exposure in the walkway shall not exceed 0.65 W/cm^2. The approximate equivalent human exposure shall be calculated by multiplying the maximum actual radiometer reading for the test in W/cm^2 at the radiometer by

$$0.31(\tan^2 \theta/_2 + 1)/\tan^2 \theta/_2 \tau$$

where:

θ = the total view angle of the test radio meter

τ = the corrosion for absorption due to humidity

Table 4-4.7.2 shall be used to determine the appropriate τ.

Table 4-4.7.2 τ Factors

Relative Humidity During Test	Distance Source to Sensor 1 m	1.5 m	2 m
0 - 25%	0.96	0.95	0.94
25 - 50%	0.94	0.93	0.92
50 - 100%	0.92	0.91	0.90

(c) The framework assembly supporting the closure curtain material and mechanisms for attachment shall be capable of maintaining structural integrity when subjected to the fire defined by the time-temperature curve for external walkway wall exposure in Figure 4-4.2.

4-4.8 Test of Cab and Rotunda Slat Curtains.

4-4.8.1 The test specimen area exposed to the test fire shall not be less than 2 ft × 2 ft (0.62 m × 0.62 m) square. The test specimen shall be representative of all elements of the cab and rotunda slat curtains, including framework assembly and mechanisms for attachment to the aircraft loading walkway.

4-4.8.2 For conditions of acceptance, the test sample shall be capable of withstanding the fire-endurance test as defined by the time-temperature curve in Figure 4-4.2 appropriate for the walkway location being tested without passage of flame for a period of five minutes. Flaming shall not appear on the unexposed face.

4-4.9 Tests of Bumpers.

4-4.9.1* Bumper assemblies shall be tested in continuous contact against a simulated aircraft fuselage in a manner representative of intended usage.

4-4.9.2 The specimen shall be configured in a manner representative of actual fabrication and shall include the bumper proper and mechanism for bumper attachment to the aircraft loading walkway.

4-4.9.3 For conditions of acceptance, bumpers shall be capable of withstanding the fire-endurance test as defined by the time-temperature curve for external walkway flooring exposure in Figure 4-4.2 without passage of flame for a period of five minutes. Flaming shall not appear on the unexposed face.

4-4.10 Tests of Miscellaneous Seals and Weather-Stripping Assemblies.

4-4.10.1 The testing laboratory shall construct a steel stud wall assembly consisting of one layer of $^{1}/_{2}$-in. Type X gypsum wallboard on the exposed face. A hole shall be framed out in the center of the test wall where another steel stud/gypsum wallboard assembly shall be inserted. The smaller assembly to be inserted into the wall shall be constructed such that the opening between the test wall and the smaller assembly allows the weather stripping or seal material to fill the gap in a manner representative of end-use application. The entire assembly then shall be placed against the furnace for the required exposure.

4-4.10.2 The size of the test specimen shall not be less than 2 ft (0.62 m) long.

4-4.10.3 For conditions of acceptance, these components shall be capable of withstanding the fire-endurance test as defined by the time-temperature curve in Figure 4-4.2 appropriate for the walkway location being tested without passage of flame for a period of five minutes. Flaming shall not appear on the unexposed face.

4-5 Fire Suppression Systems.

4-5.1*

The fixed fire suppression specified in 4-1.2 shall be provided by one of the following systems:

(a) Fixed water spray system specified in 4-5.2

(b) Fixed foam system specified in 4-5.3

4-5.2

The fixed water spray system shall be of the open head, deluge type, and shall meet the requirements of NFPA 15, *Standard on Water Spray Fixed Systems for Fire Protection.* The system shall be designed so that the water is discharged directly on all walkway outer surfaces and structural members being protected. The system shall be automatically actuated, and designed for a minimum discharge duration of five minutes.

4-5.3

The fixed foam system shall be adequate to blanket the area under the walkway when positioned at the aircraft exit door(s) and for a distance of approximately 10 ft (3 m) in all directions. The system shall meet the requirements of NFPA 11, *Standard for Low-Expansion*

Foam, and NFPA 16, *Standard for the Installation of Deluge Foam-Water Sprinkler Systems and Foam-Water Spray Systems.* The system shall be automatically activated. This system shall be capable of discharging in such a manner that the protected area previously described will be free of fire for a minimum duration of five minutes.

Chapter 5 Referenced Publications

5-1

The following documents or portions thereof are referenced within this standard as mandatory requirements and shall be considered part of the requirements of this standard. The edition indicated for each referenced mandatory document is the current edition as of the date of the NFPA issuance of this standard. Some of these mandatory documents might also be referenced in this standard for specific informational purposes and, therefore, are also listed in Appendix B.

5-1.1 NFPA Publications.

National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.

NFPA 10, *Standard for Portable Fire Extinguishers*, 1994 edition.

NFPA 11, *Standard for Low-Expansion Foam*, 1994 edition.

NFPA 13, *Standard for the Installation of Sprinkler Systems*, 1996 edition.

NFPA 14, *Standard for the Installation of Standpipe and Hose Systems*, 1996 edition.

NFPA 15, *Standard for Water Spray Fixed Systems for Fire Protection*, 1996 edition.

NFPA 16, *Standard for the Installation of Deluge Foam-Water Sprinkler and Foam-Water Spray Systems*, 1995 edition.

NFPA 31, *Standard for the Installation of Oil-Burning Equipment*, 1997 edition.

NFPA 54, *National Fuel Gas Code*, 1996 edition.

NFPA 70, *National Electrical Code*, 1996 edition.

NFPA 72, *National Fire Alarm Code*, 1996 edition.

NFPA 82, *Standard on Incinerators and Waste and Linen Handling Systems and Equipment*, 1994 edition.

NFPA 90A, *Standard for the Installation of Air Conditioning and Ventilating Systems*, 1996 edition.

NFPA 91, *Standard for Exhaust Systems for Air Conveying of Materials*, 1995 edition.

NFPA 96, *Standard for Ventilation Control and Fire Protection of Commercial Cooking Operations*, 1994 edition.

NFPA *101*, *Life Safety Code*, 1997 edition.

NFPA 220, *Standard on Types of Building Construction*, 1995 edition.

NFPA 253, *Standard Method of Test for Critical Radiant Flux of Floor Covering Systems Using a Radiant Heat Energy Source*, 1995 edition.

NFPA 255, *Standard Method of Test of Surface Burning Characteristics of Building Materials*, 1996 edition.

NFPA 407, *Standard for Aircraft Fuel Servicing*, 1996 edition.

NFPA 409, *Standard on Aircraft Hangars*, 1995 edition.

NFPA 701, *Standard Methods of Fire Tests for Flame-Resistant Textiles and Films*, 1996 edition.

5-1.2 ASTM Publications.

American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103.

ASTM Test Method C569, *Standard Test Method for Indentation Hardness of Preformed Thermal Insulations*, 1983.

Appendix A Explanatory Material

This appendix is not a part of the requirements of this NFPA document but is included for informational purposes only.

A-1-2 The adequacy and usefulness of airport terminal buildings depends, to a large extent, on the fire resistance of their construction and the fire protection provided within the buildings.

The provision of aircraft rescue and fire-fighting equipment at airports meeting the recommendations of NFPA 403, *Standard for Aircraft Rescue and Fire Fighting Services at Airports*, and NFPA 414, *Standard for Aircraft Rescue and Fire Fighting Vehicles*, will be useful in controlling ramp fires. The provision of hydrants on the ramp side of airport terminal buildings will assist in meeting supplemental fire protection needs in this area.

A-1-4 Airport Terminal Building. The term "Terminal" is sometimes applied to airport facilities other than those serving passengers, such as cargo and freight facilities and fueling-handling facilities. These facilities are covered by other NFPA standards such as NFPA 513, *Standard for Motor Freight Terminals*, and NFPA 30, *Flammable and Combustible Liquids Code*.

A-1-4 Approved. The National Fire Protection Association does not approve, inspect, or certify any installations, procedures, equipment, or materials; nor does it approve or evaluate testing laboratories. In determining the acceptability of installations, procedures, equipment, or materials, the authority having jurisdiction may base acceptance on compliance with NFPA or other appropriate standards. In the absence of such standards, said authority may require evidence of proper installation, procedure, or use. The authority having jurisdiction may also refer to the listings or labeling practices of an organization that is concerned with product evaluations and is thus in a position to determine compliance with appropriate standards for the current production of listed items.

A-1-4 Authority Having Jurisdiction. The phrase "authority having jurisdiction" is used in NFPA documents in a broad manner, since jurisdictions and approval agencies vary, as do their responsibilities. Where public safety is primary, the authority having jurisdiction may be a federal, state, local, or other regional department or individual such as a fire chief; fire marshal; chief of a fire prevention bureau, labor department, or health department; building official; electrical inspector; or others having statutory authority. For insurance purposes, an insurance inspection department, rating bureau, or other insurance company representative may be the authority having jurisdiction. In many circumstances, the property owner or his or her designated agent assumes the role of the authority having jurisdiction; at government installations, the commanding officer or departmental official may be the authority having jurisdiction.

A-1-4 Listed. The means for identifying listed equipment may vary for each organization concerned with product evaluation; some organizations do not recognize equipment as listed unless it is also labeled. The authority having jurisdiction should utilize the system employed by the listing organization to identify a listed product.

A-2-1.1 Building construction types are defined in NFPA 220, *Standard on Types of Building Construction.* The following material is extracted verbatim from NFPA 220, 1995 edition and is included here as a convenience for users of this standard. Any requests for Formal Interpretations (FIs) or Tentative Interim Amendments (TIAs) on the following material should be directed to the Technical Committee on Building Construction.

> **3-1 Type I (443 or 332).** Type I construction shall be that type in which the structural members, including walls, columns, beams, girders, trusses, arches, floors, and roofs, are of approved noncombustible or limited-combustible materials and shall have fire resistance ratings not less than those specified in Table 3-1.

Table 3-1 Fire-Resistance Ratings (in Hours) for Type I Through Type V Construction

	Type I		Type II			Type III		Type IV	Type V	
	443	332	222	111	000	211	200	2HH	III	000
Exterior Bearing Walls -										
Supporting more than one floor, columns, or other bearing walls	4	3	2	1	0[1]	2	2	2	1	0[1]
Supporting one floor only	4	3	2	1	0[1]	2	2	2	1	0[1]
Supporting a roof only	4	3	1	1	0[1]	2	2	2	1	0[1]
Interior Bearing Walls -										
Supporting more than one floor, columns, or other bearing walls	4	3	2	1	0	1	0	2	1	0
Supporting one floor only	3	2	2	1	0	1	0	1	1	0
Supporting a roof only	3	2	1	1	0	1	0	1	1	0
Columns -										
Supporting more than one floor, columns, or other bearing walls	4	3	2	1	0	1	0	H[2]	1	0
Supporting one floor only	3	2	2	1	0	1	0	H[2]	1	0
Supporting a roof only	3	2	1	1	0	1	0	H[2]	1	0
Beams, Girders, Trusses & Arches										
Supporting more than one floor, columns, or other bearing walls	4	3	2	1	0	1	0	H[2]	1	0
Supporting one floor only	3	2	2	1	0	1	0	H[2]	1	0
Supporting a roof only	3	2	1	1	0	1	0	H[2]	1	0

Floor Construction	3	2	2	1	0	1	0	H[2]	1	0
Roof Construction	2	$1^1/_2$	1	1	0	1	0	H[2]	1	0
Exterior Nonbearing Walls	0[1]	0[1]	0[1]	0[1]	0[1]	0[1]	0[1]	0[1]	0[1]	0[1]

Shaded areas represent those members that shall be permitted to be of approved combustible material.

[1]Requirements for fire resistance of exterior walls, the provision of spandrel wall sections, and the limitation or protection of wall openings are not related to construction type. They need to be specified in other standards and codes, where appropriate, and may be required in addition to the requirements of NFPA 220, *Standard on Types of Building Construction*, for the construction type.

[2]"H" indicates heavy timber members; see NFPA 220, *Standard on Types of Building Construction*, for requirements.

3-2 Type II (222, 111, or 000). Type II construction shall be that type not qualifying as Type I construction in which the structural members, including walls, columns, beams, girders, trusses, arches, floors, and roofs, are of approved noncombustible or limited-combustible materials and shall have fire resistance ratings not less than those specified in Table 3-1.

3-3 Type III (211 or 200). Type III construction shall be that type in which exterior walls and structural members that are portions of exterior walls are of approved noncombustible or limited-combustible materials, and interior structural members, including walls, columns, beams, girders, trusses, arches, floors, and roofs, are entirely or partially of wood of smaller dimensions than required for Type IV construction or of approved noncombustible, limited-combustible, or other approved combustible materials. In addition, structural members shall have fire resistance ratings not less than those specified in Table 3-1.

3-4* Type IV (2HH).

3-4.1 Type IV construction shall be that type in which exterior and interior walls and structural members that are portions of such walls are of approved noncombustible or limited-combustible materials. Other interior structural members, including columns, beams, girders, trusses, arches, floors, and roofs, shall be of solid or laminated wood without concealed spaces and shall comply with the provisions of 3-4.2 through 3-4.6. In addition, structural members shall have fire resistance ratings not less than those specified in Table 3-1.

Exception No. 1: Interior columns, arches, beams, girders, and trusses of approved materials other than wood shall be permitted, provided they are protected to provide a fire resistance rating of not less than 1 hr.

Exception No. 2: Certain concealed spaces shall be permitted by the exception to 3-4.4.

3-4.2 Wood columns supporting floor loads shall be not less than 8 in. (203 mm) in any dimension; wood columns supporting roof loads only shall be not less than 6 in. (152 mm) in the smallest dimension and not less than 8 in. (203 mm) in depth.

3-4.3 Wood beams and girders supporting floor loads shall be not less than 6 in. (152 mm) in width and not less than 10 in. (254 mm) in depth; wood beams and girders and other roof framing, supporting roof loads only, shall be not less than 4 in. (102 mm) in width and not less than 6 in. (152 mm) in depth.

3-4.4 Framed or glued laminated arches that spring from grade or the floor line and timber trusses that support floor loads shall be not less than 8 in. (203 mm) in width or depth. Framed or glued laminated arches for roof construction that spring from grade or the floor line and do not support floor loads shall have members not less than 6 in. (152 mm) in width and not less than 8 in. (203 mm) in depth for the lower half of the member height and not less than 6 in. (152 mm) in depth for the upper half of the member height. Framed or glued laminated arches for roof construction that spring from the top of walls or wall abutments and timber trusses that do not support floor loads shall have members not less than 4 in. (102 mm) in width and not less than 6 in. (152 mm) in depth.

Exception: Spaced members shall be permitted to be composed of two or more pieces not less than 3 in. (76 mm) in thickness where blocked solidly throughout their intervening spaces or where such spaces are tightly closed by a continuous wood cover plate not less than 2 in. (51 mm) in thickness, secured to the underside of the members.

Splice plates shall be not less than 3 in. (76 mm) in thickness.

3-4.5 Floors shall be constructed of splined or tongued and grooved plank not less than 3 in. (76 mm) in thickness that is covered with 1-in. (25-mm) tongue and groove flooring, laid crosswise or diagonally to the plank, or with $^1/_2$-in. (12.7-mm) plywood; or they shall be constructed of laminated planks not less than 4 in. (102 mm) in width, set close together on edge, spiked at intervals of 18 in. (457 mm), and covered with 1-in. (25-mm) tongue and groove flooring, laid crosswise or diagonally to the plank, or with $^1/_2$-in. (12.7-mm) plywood.

3-4.6 Roof decks shall be constructed of splined or tongued and grooved plank not less than 2 in. (51 mm) in thickness; or of laminated planks not less than 3 in. (76 mm) in width, set close together on edge, and laid as required for floors; or of $1^1/_8$-in. (28.6-mm) thick interior plywood (exterior glue); or of approved noncombustible or limited-combustible materials of equivalent fire durability.

Note: The dimensions used for sawn and glued laminated lumber in Section 3-4 are nominal dimensions.

3-5 Type V (111 or 000). Type V construction shall be that type in which exterior walls, bearing walls, columns, beams, girders, trusses, arches, floors, and roofs are entirely or partially of wood or other approved combustible material smaller than material required for Type IV construction. In addition, structural members shall have fire resistance ratings not less than those specified in Table 3-1.

A-2-1.2 Furniture, floor and wall coverings, and other furnishings in airport terminal occupancies, including passenger holding lounges, waiting areas, restaurant dining rooms, bars, retail stores, etc., should not be made of materials that have high combustibility or smoke-development characteristics, or both. Examples of materials that have high combustibility or smoke-development characteristics, or both, include some plastic foams, latex-rubber foam, some plastics, and some synthetic fibers. Such materials have a tendency to release combustible gases at relatively low temperatures, making them easily ignitable. These materials also release high amounts of heat energy at rapid rates when burning, thereby contributing greatly to fire propagation.

A-2-1.5 The use of glass and other glazing materials in airport terminal building walls facing the ramp should be avoided if the fueling ramp drainage inlets or the probable points of fuel spillage from aircraft are less than 100 ft (30.5 m) from such walls. This standard prohibits locating drainage inlets less than 50 ft (15.2 m) from any airport terminal building walls.

This recommendation is made because the radiant heat release from a serious fuel spill fire can be expected to break glass windows up to 75 ft (22.9 m) away and cause ignition of combustible materials within the building.

Protection provided by automatically operated outside spray nozzles is not intended to provide a safe refuge area for occupants. The degree of protection at the opening is intended to provide a period of time for the safe egress of building occupants in the vicinity of the exposed window area.

The presence of automatic sprinkler protection in the airport terminal building would be expected to control a fire initiated in the building due to an exposure fire. Glazing material above the 7-ft (2.1-m) level will not cause immediate exposure to building occupants.

Care should be exercised in the selection and adjustment of detection equipment to ensure proper operation and to guard against inadvertent operation of the system from normally fluctuating conditions. Due to the normal activity on the airport ramp, the radiated energy of a spill fire might not be received at a particular detector location but can still expose the building wall.

The aircraft terminal building is fairly unique since there can be a large population in the terminal building at the same time that a high hazard exposes the terminal. This combination presents the potential for a serious emergency situation.

An exposure evaluation should be developed for potential fuel spill points more than 50 ft (15.2 m) but less than or equal to 100 ft (30.5 m) from the airport terminal building. The exposure evaluation should describe the location and severity of potential fuel spill points and the design features that control exposure fire damage to the airport terminal building and occupants. Catastrophic crashes between aircraft or aircraft and the building are not part of the evaluation.

The exposure evaluation should include consideration of each of the following:

(a) Fuel spill points

(b) Fuel spill rates

(c) Fuel spill pool size

(d) Ramp drainage design

(e) Exposed wall construction

(f) Wall openings (windows, doors, etc.)

(g) Interior building fire protection features

The many factors affecting the exposure make each facility layout a different design problem. The building design, aircraft fueling ramp design, aircraft fueling system, and aircraft fueling ramp drainage system will affect the exposure.

The building design features affecting the degree of exposure include building construction characteristics, the size of windows facing the ramp, the presence of automatic sprinkler protection, and the exit arrangements. The exposed wall will provide a different degree of protection to the building interior and building occupants depending on the building wall construction material.

The presence of openings, particularly glass, will significantly increase the radiated energy inside the building. The extent to which the radiated energy transmission is affected will depend on the size of the opening, the opening location with respect to the spill fire, and the building arrangement inside the opening.

The aircraft fueling ramp design will affect the size and duration of a fuel spill fire. Both the direction and rate of drainage can influence the fire exposure to the airport terminal building. When the characteristics of the ramp design and the ramp drainage system are considered together, the variables, such as ramp construction material, ramp slope, drain inlet location, and drainage system capacity, will affect the exposure. Ramp drainage trenches present a different exposure to the airport terminal building wall from drain inlets to an underground piping system.

Aircraft fueling systems are generally fixed piping systems with strategically located fuel hydrants. Fuel servicing vehicles serve as the transfer mechanism between the fixed piping system and the aircraft. Refer to NFPA 407, *Standard for Aircraft Fuel Servicing,* for design considerations used in the airport fueling systems. Smaller or older airports may use tanker trucks. Tanker trucks are also used as backup to the fixed piping systems. The presence of a tanker truck at the aircraft puts a larger quantity of fuel on the ramp.

Exposure fire damage can be minimized in three different ways: physical separation, fire-resistance-rated exterior wall construction, and fire suppression systems. These protection methods can be utilized singularly or in combination.

A-2-2.2 Examples of points of flammable vapor release are fuel tank vent openings and fuel hydrant pits. Air supply intake and exhaust openings for air conditioning or ventilating equipment serving the terminal building should not be located on the ramp side of an airport terminal building. Fixed air conditioning and ventilating equipment serving aircraft only should be in a room having no openings communicating with the remainder of the terminal building.

A-2-2.3 Rooms containing coal-, gas-, or oil-fired equipment, or any room containing any other open flame device, should not have openings on the ramp side of the building. Combustion and ventilation air should be supplied from the street side or roof of the building or through a gravity louver from a nonhazardous area in the building.

A-2-3.2 The hazards to persons from jet intakes and blast, noise, propellers, etc., on the ramp should be taken into consideration in locating emergency exit points leading to ramps from the airport terminal building. A means of notification of unauthorized usage (such as an alarm system) of these emergency exits may be desirable.

A-2-5.1 The assembly portion of the terminal building may include areas such as the concourse waiting areas, baggage claim areas, and restaurants. This should exclude the kitchens, toilets, small office areas, and other areas not normally accessible to the public.

A-2-5.1.2 The exposure to the airport terminal building from the airport ramp is significant. The number of building sprinklers operating from the exposure fire may be greater than from an internal ignition source.

A-2-5.2.2 If the public fire department is responding to the "street" side of the airport terminal building, timely access to the normal alarm receiving point may be limited by emergency conditions or distance. Planned radio communication with a constantly attended alarm receiving point can assist in a more efficient response by the public fire department. The remote annunciator on the "street" side of the terminal building can provide building condition information if not otherwise available.

A-2-5.5.1 Valves should be installed to facilitate proper control and should be based on a calculation of the number of units (suppression systems and hydrants) that would be impaired when portions of the system are out of service for repair, maintenance, modification, or expansion. Valves should be so located and identified as to be readily accessible for operation. Particular attention should be given to valving the following locations:

(a) Points of connection of supplies to loops or grids

(b) Intervals in main loop

(c) Grid intersections

(d) Beginnings of laterals

(e) Each connection to hydrants

General fire flow requirements at airports should be based on the maximum fire flow demands (automatic sprinklers, hose, and supplemental systems) anticipated. To determine actual demands, the appropriate NFPA standard should be consulted. Table A-2-5.5.1 lists the range of fire flows and is given only as a guide.

Table A-2-5.5.1

Building Occupancy	Reference to Other Standards	Range of Fire Flows (sprinklers, hose, supplemental)
Terminal	NFPA 13, NFPA 15, and NFPA 416	1000 gpm - 3500 gpm
Hangar	NFPA 409	A wide range exists. For large hangars, this value could approximate 25,000 gpm
Cargo	NFPA 13, NFPA 15, NFPA 231, and NFPA 231C	1500 gpm - 4000 gpm

A-2-5.5.2 Hydrants should be placed in strategic locations on the loops or grids. Operational requirements should be considered when determining hydrant locations on or near taxiways and runways where snow and ice may be present.

A-2-5.5.3 All hydrants should be flushed and all valves operated at least once a year.

After extensive changes to the airport water supply system, full flow tests should be made in the areas affected to ensure that adequacy has been retained or expected improvements have been obtained.

Fire pumps or spare pumps should be given turnover tests at least weekly and full flow tests at least annually. Internal combustion engines driving pumps should be run once a week for at least one-half hour each time.

A-3-1.1 Consideration should be given to the hydraulic problem in disposal of surface water, safe disposal of fuel that might be spilled on the ramp, and the gradient to be overcome in the movement of aircraft. A ratio of 40,000 ft^2 (3716 m^2) per drainage inlet should not be exceeded with minimum flow distances to drains, but drain inlets should be located so as not to endanger aircraft placements within the ramp area so described.

A-3-1.2 Figures A-3-1.2(a) and (b) illustrate two possible fueling ramp drainage arrangements.

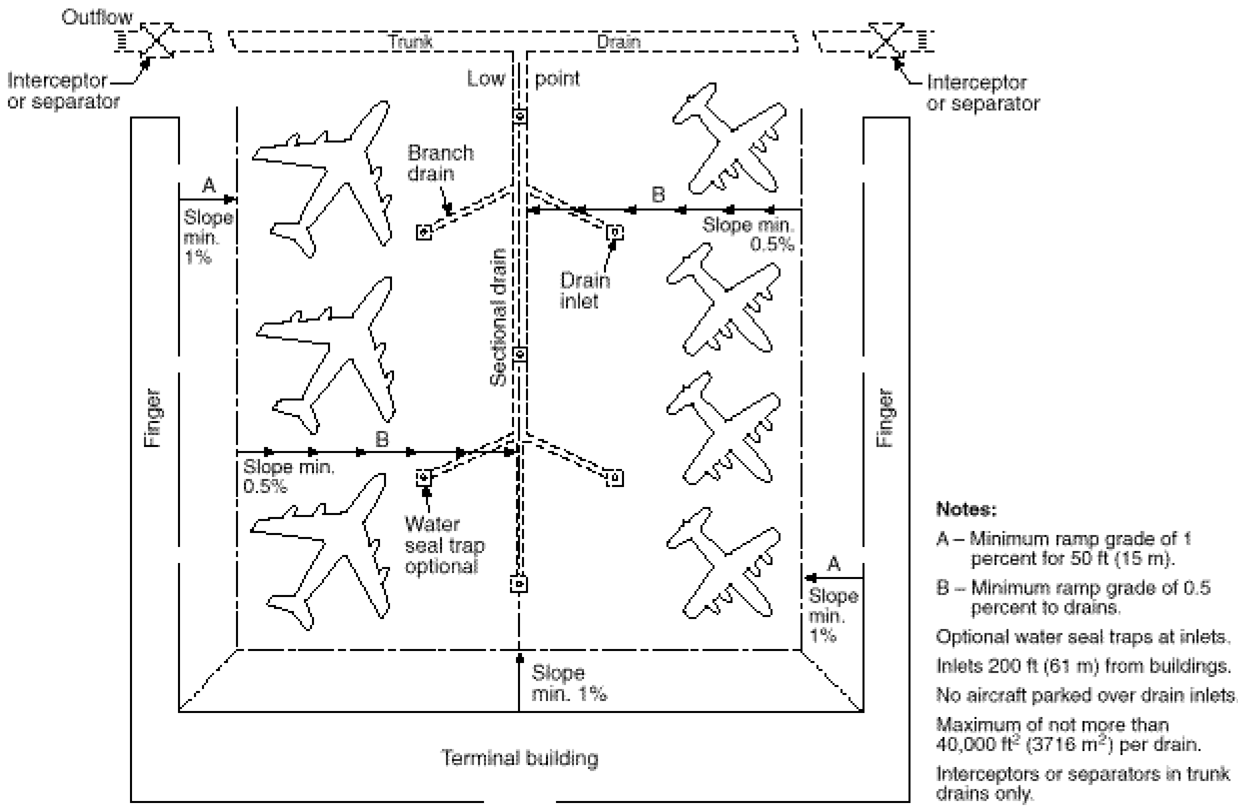


Figure A-3-1.2(a) One possible arrangement of an aircraft fueling ramp drainage system using the optional trapped drain inlets.

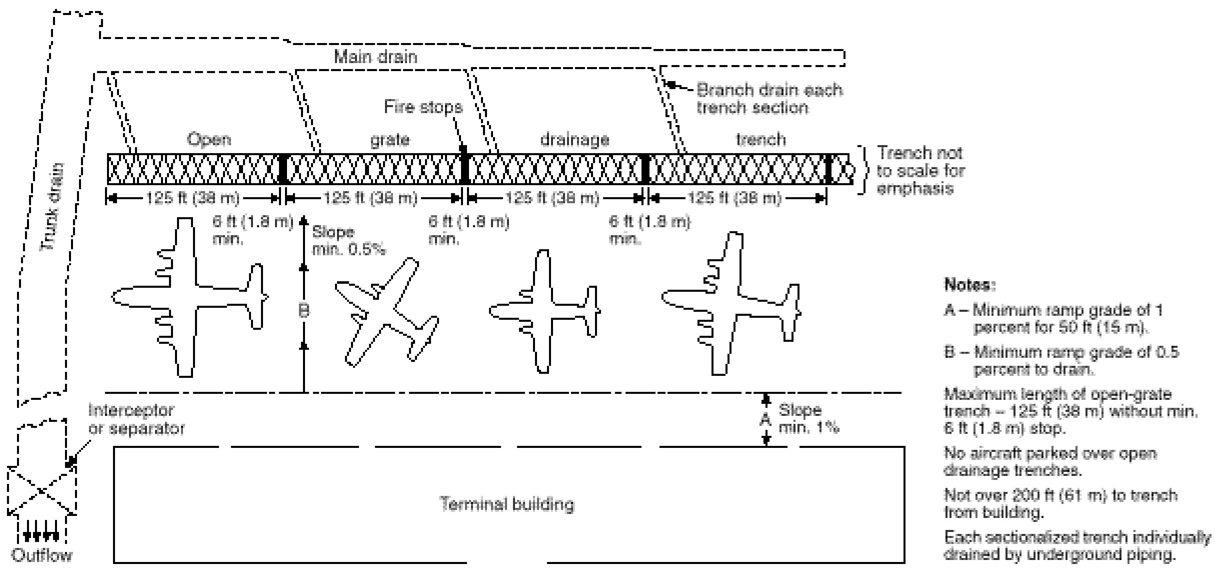


Figure A-3-1.2(b) Another possible arrangement of an aircraft fueling ramp drainage system using an open-grate drainage trench.

A-3-1.7 The individual drain is intended to prevent flow of a spill in one trench from flowing through other trenches. Refer to Figure A-3-1.2(b).

A-3-2.1 It is suggested that maintenance checks be conducted at least four times a year and more often if climatic or other local conditions dictate.

A-4-2.1 Interior Atmospheres. Fire tests have shown that smoke and toxic products generated within the walkway from the decomposition of certain materials can hinder the egress of passengers from an aircraft during a fire emergency. Existing technology does not permit establishment of performance criteria for acceptable levels of smoke density and toxic products. Where the tests specified indicate that materials used in walkway construction can degrade, thermal barriers or insulation should be used to reduce the rate of temperature rise and to delay the decomposition of susceptible materials. Of particular concern are those materials used in floor construction, such as plywood and floor coverings. The insulation materials used should produce minimal smoke under fire exposure conditions.

A-4-2.5 The source of uncontaminated air is normally from the airport terminal building.

A-4-2.6 Aircraft loading walkways can be used for a return air plenum as part of a system that provides ventilation for the aircraft. This system can create a positive or negative pressure in the walkway during normal operation and might use air from the ramp for make-up. Systems of this type, as well as any exhaust fans on the walkway, are therefore to be automatically shut down in the event of a fire emergency outlined in 4-1.1.

A-4-4.5.3 The 10-minute fire endurance test period specified is to give those conducting the tests a better opportunity to discriminate between different test samples.

A-4-4.9.1 A suggested test configuration is to construct two steel stud frames of suitable size to cover the test furnace when laying side-by-side and flat. On the exposed face of each frame, one layer of $^{1}/_{2}$-in. Type X gypsum board should be fastened to the steel stud framing. To the edge of one frame, the bumper assembly should be fastened in a manner representative of end-use application. To the edge of the other frame, a sheet of $^{1}/_{2}$-in. thick steel having dimensions such that there is a minimum of 6-in. of steel extending past the bumper assembly in all directions should be fastened to the steel studs. The steel plate is used to simulate the aircraft sidewall. The two frames are brought together such that the bumper assembly is placed in firm contact with the simulated aircraft sidewall and the two frames are fastened together. This unit becomes the test assembly and is placed on the test furnace for the fire exposure period. *(See Figure A-4-4.9.1 for a sketch of the test assembly.)*

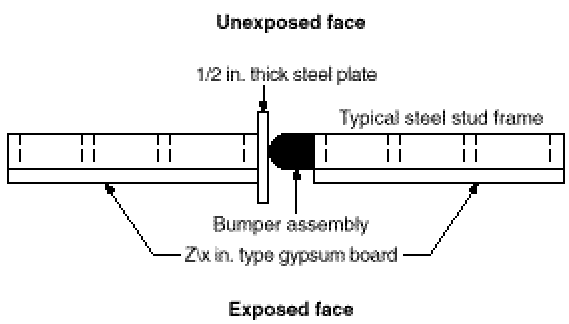


Figure A-4-4.9.1 Proposed method for testing of bumper assemblies.

A-4-5.1 Fire Protection System Actuation Design Recommendation. The design of automatic actuation equipment should take into consideration the possibility of heat or pressure sources that could exist in the areas where these systems are installed (e.g., operation of turbine engines in the vicinity, heat-creating equipment on the ramp, hot air curtains at terminal openings, etc.).

Appendix B Referenced Publications

B-1 The following documents or portions thereof are referenced within this standard for informational purposes only and are thus not considered part of the requirements of this standard unless also listed in Chapter 5. The edition indicated here for each reference is the current edition as of the date of the NFPA issuance of this standard.

B-1.1 NFPA Publications. National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.

NFPA 30, *Flammable and Combustible Liquids Code*, 1996 edition.

NFPA 220, *Standard on Types of Building Construction*, 1995 edition.

NFPA 403, *Standard for Aircraft Rescue and Fire Fighting Services at Airports*, 1993 edition.

NFPA 407, *Standard for Aircraft Fuel Servicing*, 1996 edition.

NFPA 414, *Standard for Aircraft Rescue and Fire Fighting Vehicles*, 1995 edition.

NFPA 513, *Standard for Motor Freight Terminals*, 1994 edition.

B-1.2 Other Publications.

B-1.2.1 References on Heat Exposures to Man.

"Effects of Extreme Heat on Man," Buettner, K. (PB 16.026 U.S. Dept. of Commerce, FSTI), *Journal of the American Medical Association*, Vol. 144, No. 9, pp. 732-738 (October 28, 1950).

Tolerances to Thermal Extremes in Aerospace Activities (AM 70-22), Office of Aviation Medicine, U.S. Dept. of Transportation, FAA (December, 1970).

Flight Surgeon's Guide, Department of the Air Force (AFP-161-18), pp. 5-7 (December 27, 1968).

NFPA 418

1995 Edition

Standard for Heliports

1995 Edition

This edition of NFPA 418, *Standard for Heliports*, was prepared by the Technical Committee on Helicopter Facilities and acted on by the National Fire Protection Association, Inc., at its Annual Meeting held May 22-25, 1995, in Denver, CO. It was issued by the Standards Council on July 21, 1995, with an effective date of August 11, 1995, and supersedes all previous editions.

This edition of NFPA 418 was approved as an American National Standard on August 11, 1995.

Changes other than editorial are indicated by a vertical rule in the margin of the pages on which they appear. These lines are included as an aid to the user in identifying changes from the previous edition.

Origin and Development of NFPA 418

The development of NFPA 418 began in 1965 after the NFPA Sectional Committee on Aircraft Hangars and Airport Facilities was asked to provide guidance on the construction and protection of elevated heliports. Earlier work had been done by the NFPA Sectional Committee on Aircraft Rescue and Fire Fighting with regard to fire protection in the event of accidents during flight operations, and the NFPA Sectional Committee on Aircraft Fuel Servicing developed the safeguards needed for the prevention of fire accidents during fueling operations at such locations. In 1967, a Tentative Standard on Elevated Heliport Construction and Protection was approved at the NFPA Annual Meeting. The 1968 text was a revision of the tentative standard (including a change in title). The 1973 edition was a complete revision of the 1968 edition. Further amendments were made in 1979. The title of the 1990 edition of this standard was changed from Standard on Roof-top Heliport Construction and Protection. The 1990 edition added chapters for land-based facilities and offshore heliports.

The standard was revised for 1995.

Technical Committee on Helicopter Facilities

Donald J. Slater, Jr., *Chair*
Allendale Insurance Co., WA

Michael E. Aaron, Rolf Jensen & Assoc., Inc., IL

Joseph A. Behnke, Ansul Fire Protection, WI

William E. Davis, Heliport Systems Inc., NJ

Dana P. DeWoody, Shell Corp. Aviation, TX
Rep. Helicopter Safety Advisory Conference

Steve C. Dryden, Black & Veatch, MO

Beryl Gamse, McDowell Owens Engr, Inc., TX

Martin D. Goerl, Great Lakes Chemical Corp., NJ
Rep. Fire Equipment Mfrs. Assn. Inc.

Frank P. Lambert, Cigna Corp., PA
Rep. American Insurance Services Group, Inc.

John J. McGowan, The Port Authority of NY & NJ, NJ
Rep. Airport Operators Council Int'l Inc.

Ronald J. Megasko, Marsh & McLennan Protection Consultants, PA

Jack Poole, Poole Fire Protection Engr, Inc., KS

Stephanie V. Slavin, Aviation Business Consultants Inc., FL

Raymond A. Syms, Raymond A. Syms & Assoc., NJ

Alternate

Lanny D. Rider, The Port Authority of NY & NJ, NJ
(Alt. to J. J. McGowan)

Nonvoting

J. Walter Coon, Black and Veatch, MO
(Member Emeritus)

Mark T. Conroy, NFPA Staff Liaison

This list represents the membership at the time the Committee was balloted on the text of this edition. Since that time, changes in the membership may have occurred.

NOTE: Membership on a Committee shall not in and of itself constitute an endorsement of the Association or any document developed by the Committee on which the member serves.

Committee Scope: This Committee shall have primary responsibility for documents on the fire protection criteria for the design and construction of elevated and ground level heliports, helistops, and helipads; fire protection requirements for heliports, helistops, and helipads; and requirements for rescue and fire-fighting operations at heliports, helistops, and helipads.

NFPA 418

Standard for

Heliports

1995 Edition

NOTICE: An asterisk (*) following the number or letter designating a paragraph indicates explanatory material on that paragraph in Appendix A.
Information on referenced publications can be found in Chapter 6 and Appendix B.

Chapter 1 Administration

1-1 Scope.

1-1.1

This standard specifies the minimum requirements for fire protection for heliports.

1-1.2

Temporary landing sites and emergency evacuation facilities are outside the scope of this standard.

1-2 Purpose.

The purpose of this standard is to establish minimum fire safety requirements for operation at heliports for the protection of persons, aircraft, and other property.

1-3 Definitions.

Approved.* Acceptable to the authority having jurisdiction.

Authority Having Jurisdiction.* The organization, office, or individual responsible for approving equipment, an installation, or a procedure.

Critical Area. The area calculated to be one-half the overall length of the helicopter multiplied by three times the width of the widest portion of the fuselage. (*See A-3-6.1 for additional information.*)

Emergency Evacuation Facility. A designated and clear area at rooftop or ground level intended exclusively for emergency/rescue operations by helicopters.

Foam Fire Extinguishing System. A low-expansion foam fire extinguishing system designed and installed in accordance with NFPA 11, *Standard for Low-Expansion Foam*. It can be a fixed discharge outlet system utilizing fixed storage and piping connected to fixed outlets or monitor nozzles and manually activated by pushing a button on a console or a pull station. It also can be a hose line system connected to fixed storage.

Heliport. An identifiable area located on land, on water, or on a structure, that also includes any existing buildings or facilities thereon, used or intended to be used for landing and takeoff of helicopters. The term heliport applies to all sites used or intended to be used for the landing and takeoff of helicopters.

Listed.* Equipment or materials included in a list published by an organization acceptable to the authority having jurisdiction and concerned with product evaluation that maintains periodic inspection of production of listed equipment or materials and whose listing states either that the equipment or material meets appropriate standards or has been tested and found suitable for use in a specified manner.

Offshore Landing Heliport. A heliport located on fixed or mobile structures and vessels in a marine environment that do not have means of entry and egress connected directly to shore.

Overall Length. The length of the helicopter from the main rotor fully extended to the tail rotor fully extended.

Practical Critical Fire Area. The area, for foam discharge purposes, calculated as one-half the fuselage length multiplied by three times the fuselage width. (*See also A-3-6.1.*)

Rooftop Landing Pad. The entire load-bearing surface intended for the landing, takeoff, and parking of helicopters.

Shall. Indicates a mandatory requirement.

Should. Indicates a recommendation or that which is advised but not required.

Temporary Landing Site. A site intended to be used for a period of less than 30 consecutive days, and for no more than 10 operations per day.

Chapter 2 General Requirements — Land-Based Facilities

2-1* Plans.

Plans for construction and protection of heliports shall be approved by the authority having jurisdiction.

2-2 Tank Locations.

Aboveground flammable liquid storage tanks, compressed gas storage tanks, and liquefied gas storage tanks shall be laterally located at least 50 ft (15.2 m) from the edge of takeoff and landing areas as defined in FAA A/C 150/5390-2, *Heliport Design Advisory Circular*.

2-3 Fire-Fighting Access.

2-3.1

The heliport shall have at least one access point for fire-fighting/rescue personnel. Where practical, a second access point shall be available and located as remotely as possible from the other.

2-3.2

Fences shall not prevent rapid access by fire-fighting/rescue personnel.

2-4 Landing Pad Pitch.

The heliport shall be pitched or sloped so that drainage flows away from access points and passenger holding areas.

2-5 No Smoking.

No smoking shall be permitted within 50 ft (15.2 m) of the landing pad edge. No smoking signs shall be erected at access/egress points to the heliport.

2-6 Fueling System.

Fueling systems shall be designed in accordance with NFPA 407, *Standard for Aircraft Fuel Servicing*.

Chapter 3 Rooftop Landing Facilities — Additional Protection

3-1 Structural Support.

Main structural support members that could be exposed to a fuel spill shall be made fire resistant using listed materials and methods to provide a fire-resistance rating of not less than 2 hours.

3-2 Landing Pad Pitch.

The rooftop landing pad shall be pitched to provide drainage that flows away from passenger holding areas, access points, stairways, elevator shafts, ramps, hatches, and other openings.

3-3 Landing Pad Construction Materials.

The rooftop landing pad surface shall be constructed of noncombustible, nonporous materials that are approved. The contiguous building roof covering within 50 ft (15.2 m) of the landing pad edge shall have a Class A rating.

3-4* Means of Egress.

At least two approved means of egress from the rooftop landing pad edge shall be provided and shall be remotely located from each other to the extent practical.

3-4.1

For heliports occupied by 50 or more people, two approved means of egress from the roof shall be provided and shall be remotely located from each other to the extent practical but shall not be located less than 30 ft (9.1 m) from each other. For heliports occupied by fewer than 50 people, one approved means of egress from the roof shall be provided.

3-4.2

Means of egress from the rooftop landing pad and roof shall not obstruct flight operations.

3-5 Fire-Fighting Access.

The helicopter rooftop landing pad shall have at least two access points for fire-fighting purposes. Access for fire-fighting personnel through the landing pad egress shall be permitted.

3-6 Fire Protection.

A foam fire extinguishing system shall be designed and installed to protect the rooftop landing pad.

Exception No. 1: A foam fire extinguishing system shall not be required for heliports located on parking garages, unoccupied buildings, or other similar unoccupied structures.

Exception No. 2: For H-1 heliports, two portable foam extinguishers, each having a rating of 20-A:160-B, shall be permitted to be used to satisfy this requirement.

3-6.1*

The foam discharge rate shall be as follows:

AFFF	0.10 gpm/ft^2 [4.1 (L/min)/m^2]
Fluoroprotein	0.16 gpm/ft^2 [6.5 (L/min)/m^2]
Protein	0.20 gpm/ft^2 [8.1 (L/min)/m^2]

3-6.2

The area of application of foam discharge for fixed discharge outlet systems shall be the entire rooftop landing pad. The duration shall be 5 minutes.

3-6.3*

The area of application of foam discharge for hose line systems shall be the practical critical fire area for the category of the helicopter landing facility. The duration shall be 2 minutes.

Table 3-6.3 Practical Critical Fire Areas

Category	Helicopter Overall Length[1]	Practical Critical Fire Area
H-1	Up to but not including 50 ft (15.2 m)	375 ft^2 (34.8 m^2)
H-2	From 50 ft (15.2 m) up to but	840 ft^2 (78.0 m^2)

	not including 80 ft (24.4 m)	
H-3	From 80 ft (24.4 m) up to but not including 120 ft (36.6 m)	1440 ft^2 (133.8 m^2)

[1]Helicopter length, including the tail boom and the rotors.

3-6.4

The water supply for the foam system shall be from a reliable source, approved by the authority having jurisdiction.

3-6.4.1 Fire pumps, if used, shall be installed in accordance with NFPA 20, *Standard for the Installation of Centrifugal Fire Pumps*.

3-6.4.2 Standpipes and hose stations, if used, shall be installed in accordance with NFPA 14, *Standard for the Installation of Standpipe and Hose Systems*.

3-6.4.3 Where freezing is possible, adequate freeze protection shall be provided.

3-6.5

The foam components shall be installed in a readily accessible area of the heliport and shall not penetrate the primary approach, departure, and transitional surfaces defined in paragraphs 3J, 3K, 3L, 13, and 21 of FAA A/C 150/5390-2, *Heliport Design Advisory Circular*.

3-6.6

At facilities where there is more than one rooftop landing pad, the supply of foam available shall be sufficient to cover an incident on at least one of the pads.

3-6.7

Where fixed foam systems utilizing fixed deck nozzles or oscillating foam turrets, or both, are installed, system components shall be listed or approved.

3-7 Standpipes.

If a building with a rooftop heliport is supplied with a standpipe system, a Class II standpipe shall be extended to the roof level on which the rooftop heliport is located. Such standpipe systems shall be installed in accordance with NFPA 14, *Standard for the Installation of Standpipe and Hose Systems*.

3-8 Fire Alarm.

Where buildings are provided with a fire alarm system, a manual pull station shall be provided for each designated means of egress from the roof. (*See 3-4.1.*)

Chapter 4 Offshore Heliports

4-1* Plans.

Plans for construction and protection of heliports located on fixed and mobile offshore installations shall be approved by the authority having jurisdiction.

4-2 Fire-Fighting Access.

The heliport shall have at least one access point for fire-fighting/rescue personnel. Where practical, a second access point shall be available and shall be located as remotely as possible from the other.

4-3 Landing Pad Pitch.

Heliports shall be designed to prevent the standing collection of liquids and to prevent liquids from spreading to or spilling on accommodation spaces or working spaces.

Chapter 5 Portable Fire Extinguishers

5-1 Quantity and Rating.

At least one portable fire extinguisher as specified in Table 5-1 shall be provided for each takeoff and landing area, parking area, and fuel storage area.

Exception: This requirement shall not apply to unattended ground level heliports.

Table 5-1 Minimum Ratings of Portable Fire Extinguishers for Heliport Categories

Category	Helicopter Overall Length[1]	Minimum Rating
H-1	Up to but not including 50 ft (15.2 m)	4-A:80-B
H-2	From 50 ft (15.2 m) up to, but not including, 80 ft (24.4 m)	10-A:120-B
H-3	From 80 ft (24.4) up to, but not including, 120 ft (36.6 m)	30-A:240-B

[1]Helicopter length, including the tail boom and the rotors.

5-2 Servicing.

Portable fire extinguishers shall comply with NFPA 10, *Standard for Portable Fire Extinguishers*, Chapters 1, 4, 5, and 6.

Chapter 6 Referenced Publications

6-1

The following documents or portions thereof are referenced within this standard and shall be considered part of the requirements of this document. The edition indicated for each reference is the current edition as of the date of the NFPA issuance of this document.

6-1.1 NFPA Publications.

National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.

NFPA 10, *Standard for Portable Fire Extinguishers*, 1994 edition.

NFPA 11, *Standard for Low-Expansion Foam*, 1994 edition.

NFPA 14, *Standard for the Installation of Standpipe and Hose Systems*, 1993 edition.

NFPA 20, *Standard for the Installation of Centrifugal Fire Pumps*, 1993 edition.

NFPA 407, *Standard for Aircraft Fuel Servicing*, 1990 edition.

6-1.2 Other Publication.

6-1.2.1 FAA Publication. Federal Aviation Administration, Department of Transportation, Distribution Unit, M-494.3, Washington, DC 20590.

FAA A/C 150/5390-2, *Heliport Design Advisory Circular*, January 4, 1988.

Appendix A Explanatory Material

This Appendix is not a part of the requirements this NFPA document but is included for informational purposes only.

A-1-3 Approved.

The National Fire Protection Association does not approve, inspect, or certify any installations, procedures, equipment, or materials; nor does it approve or evaluate testing laboratories. In determining the acceptability of installations, procedures, equipment, or materials, the authority having jurisdiction may base acceptance on compliance with NFPA or other appropriate standards. In the absence of such standards, said authority may require evidence of proper installation, procedure, or use. The authority having jurisdiction may also refer to the listings or labeling practices of an organization concerned with product evaluations that is in a position to determine compliance with appropriate standards for the current production of listed items.

A-1-3 Authority Having Jurisdiction.

The phrase “authority having jurisdiction” is used in NFPA documents in a broad manner, since jurisdictions and approval agencies vary, as do their responsibilities. Where public safety is primary, the authority having jurisdiction may be a federal, state, local, or other regional department or individual such as a fire chief; fire marshal; chief of a fire prevention bureau, labor department, or health department; building official; electrical inspector; or others having statutory authority. For insurance purposes, an insurance inspection department, rating bureau, or other insurance company representative may be the authority having jurisdiction. In many circumstances, the property owner or his or her designated agent assumes the role of the authority having jurisdiction; at government installations, the commanding officer or departmental official may be the authority having jurisdiction.

A-1-3 Listed.

The means for identifying listed equipment may vary for each organization concerned with product evaluation, some of which do not recognize equipment as listed unless it is also labeled. The authority having jurisdiction should utilize the system employed by the listing organization to identify a listed product.

A-2-1

FAA A/C 150/5390-2, *Heliport Design Advisory Circular*, contains design and construction information on heliports. This advisory circular provides for adequate clearance between operating aircraft and buildings or structures located at the heliport. The FAA advisory circular should be consulted to ensure that adequate safe practice and facilities are maintained.

A-3-4

For further information on exit principles, see NFPA *101®*, *Life Safety Code®*.

A-3-6.1

Where personnel trained in the operations of the equipment are in attendance, a hose line system is preferred.

The calculations used to develop the minimum extinguishing agent quantities and discharge rates presented in Table A-3-6.1 for rooftop heliports include the following factors:

(a) *Aircraft Size.* Reflects the potential level of risk, e.g., passenger load; the potential fire load, e.g., fuel capacity; and the dimensions, i.e., fuselage length and width, that allow the identification of a meaningful operational objective, i.e., the area to be rendered fire-free (controlled or extinguished).

(b) *Relative Effectiveness of Agent Selected.* Represented by the specific application rate identified for each of the common generic foam concentrate types.

(c) *Time Required to Achieve Control.* Large-scale fire tests, empirical data, and field experience indicate that 1 minute is both a reasonable and a necessary operational objective.

(d) *Time Required to Maintain Controlled Area Fire-Free.* An operational objective that provides a safety factor for the initial fire attack while waiting for the arrival of backup support.

The calculation method is supported by research and experimental work done mainly at the U.S. FAA's Technical Center. It was developed by the "Rescue and Firefighting Panel II" (RFFP II), a group of international experts in the field, convened by the International Civil Aviation Organization, Montreal Canada, circa 1970.

The RFFP II initially focused on the "Theoretical Critical Fire Area," which was identified in the FAA's large-scale fire tests as "... the area adjacent to the fuselage extending outward in all directions to a limit beyond which a large fuel fire would not melt an aluminum fuselage, regardless of the fire exposure time." For this concept to be useful, specific information about the size of the area was needed. Again, using the FAA Technical Center's work as a basis, the RFFP II's working definition of the Theoretical Critical Fire Area (TC) is "the area adjacent to an aircraft in which fire must be controlled." This definition implies control of the fire within a specific area. In order to achieve this, dimensions need to be determined. Formulas 1 and 2, which follow, were developed from that earlier work. Using these formulas, the size of the area of interest can be calculated. For example:

1. Where L<65 ft: $TC = L \times (40 \text{ ft} + W)$

or

1a. L<20 m: $TC = L \times (12 \text{ m} + W)$

and

2. Where L>65 ft: $TC = L \times (100 \text{ ft} + W)$

or

2a. L>20 m: $TC = L \times (30 \text{ m} + W)$

Where: L = average aircraft length

W = average width of aircraft served at the airport of interest.

Conceptually, the TC serves as a means for assessing the magnitude of the potential fire hazard of the aircraft accident environment. It *does not represent* the average, maximum, or minimum spill fire size associated with a particular aircraft. However, it does represent a starting point for determining realistic fire extinguishing agent requirements. The formulas allow for the calculation of the TC area for different sizes of aircraft. They are widely accepted throughout the aircraft fire service community and are applied as described in the following paragraphs.

A 1970 study concluded that in survivable aircraft crashes a “practical fire area” should be considered that was smaller than the “theoretical area.” Detailed criteria for the practical fire area and the related quantities of extinguishing agents were formulated during the second meeting of the RFFP II. In developing its material, the panel’s work included a study of the quantities of agents used on actual fires. In 99 out of 106 such fires, the quantities of agents used were less than those recommended by the theoretical critical fire area calculations.

As a result, RFFP II developed material recommending that the practical area be approximately two-thirds the theoretical area [*see Figure A-3-6.1(a)*]. This principle has been adopted by the ICAO, the NFPA, and the U.S. FAA in the development of tables that show extinguishing agent volumes for their respective standards and recommended practices. The practical critical fire area (PC) for fixed-wing aircraft is commonly expressed as follows:

3. (practical critical fire area) =
(0.67) × (theoretical critical fire area)

or

3a. PC = (0.67) (TC)

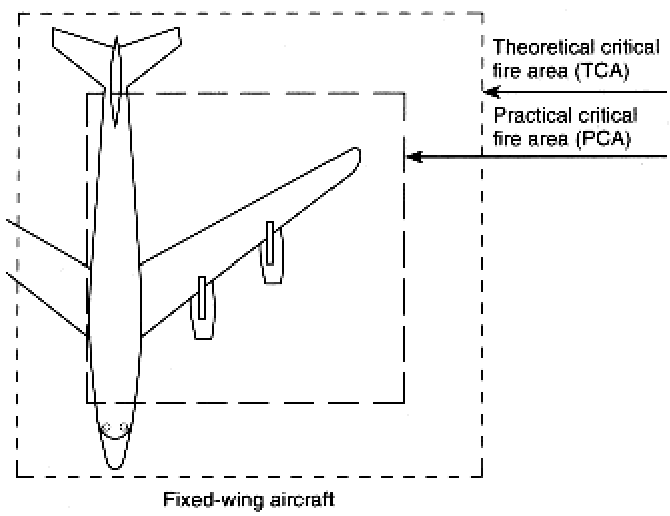


Figure A-3-6.1(a) Practical critical fire area relative to theoretical critical fire area.

In adapting the fixed-wing fire protection methodology to helicopters, the committee considered the following additional factors that make the fire protection problem of helicopters (rotary-wing aircraft) unique:

(a) *Occupied Space.* Relative to its fixed-wing counterpart, a smaller portion of the overall aircraft length is occupied.

(b) *Fuel Quantities and Location.* Fuel tanks are not located in the “wings” or rotor blades, and relatively small quantities of fuel are involved.

(c) *Impact Energy.* Relative to the fixed-wing counterpart, a helicopter accident generally occurs at slow ground speeds.

(d) *Expected Aircraft Size.* In general, heliports are designed for the largest helicopter expected to utilize the facility, not the median size for the category. (*See Table 3-6.3.*)

After considering both the factors involved in the fixed-wing methodology and those factors that are unique to helicopters, the committee arrived at a "Theoretical Critical Area" for helicopters that includes a longitudinal dimension of half the overall length of the helicopter and a width equal to three times the fuselage width. In addition, in the absence of any data that suggested a more appropriate alternative, the "practical critical fire area" has been determined to be 100 percent of the "theoretical critical area." [*See Figure A-3-6.1(b).*]

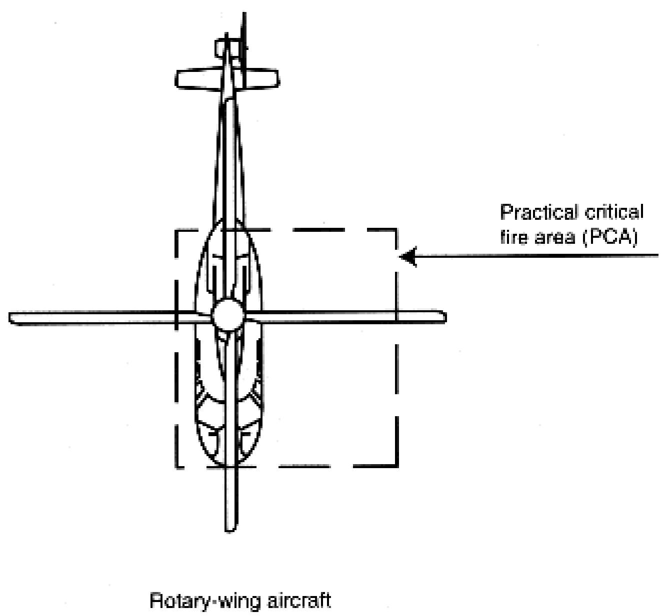


Figure A-3-6.1(b) Practical critical fire area for helicopters.

Another established principle is the distinction between control and extinguishment of a fire. Test data and a wide range of field experience indicate that the quantities of foam agent needed to control and extinguish an aircraft fire should be determined separately. This principle is expressed in items 1 through 6 as follows:

1. Where Q_1= Volume of agent needed for 1-minute control of PC

and

2. Q_2 = Volume of agent needed for continued control or complete extinguishment of fire related to PC, or both.

3. Therefore: $Q = Q_1 + Q_2$ = Minimum agent volume for effective fire service operations.

The relationship between Q_1 and Q_2 as they were developed by the committee that studied the fixed-wing fire protection problem is as follows:

4. Q_1 = (application rate) × (practical critical area)

or

4a. Q_1 = (AR)(PC) Where the "application rate" is the unit volume of agent applied to a unit area of fire in a unit time; the exact units such as gpm/ft^2 or lpm/m^2 depend on the units convention being used.

5. $Q_2 = f(Q_1)$ And it has been determined that, for all categories of heliports, f = 1.

6. Therefore: Q = 2[(AR)(PC)]

A sample calculation of the total water quantity, Q, needed where aqueous film-forming foam concentrate is to be used at each of the three categories of heliport is provided in Tables A-3-6.1(a) and (b). A similar set of water quantities can be calculated for any other foam concentrate for which an accepted application rate is known. The value for the AFFF application rate in column 5 of Tables A-3-6.1(a) and (b) is substituted and the indicated calculations are performed to obtain the value of Q for the specific foam concentrate to be used.

Table A-3-6.1(a) Method to Determine Helicopter Critical Fire Area and Required Minimum Amount of Water for a Hose Line (AFFF) System

NFPA/ICAO Heliport Category				½ × O.L. of Largest Helicopter[1]		Fuselage Width Tripled[2]		Practical Crital Fire Area		Application Rate (gpm/ft^2)		Q_1 Water to Control within 1 Min		Q_2 Reserve to Extinguish		Q Total Water to Extinguish
H-1	0 ft	<	50 ft	25 ft	×	15 ft	=	375 ft^2	×	0.10	=	37.5 U.S. gal	+	100%	=	75 U.S. gal
H-2	50 ft	<	80 ft	40 ft	×	21 ft	=	840 ft^2	×	0.10	=	89 U.S. gal	+	100%	=	168 U.S. gal
H-3	80 ft	<	120 ft	60 ft	×	24 ft	=	1440 ft^2	×	0.10	=	199 U.S. gal	+	100%	=	288 U.S. gal

[1]O.L. = Overall length, measured from tip of main rotor fully extended to tip of tail rotor fully extended.
[2]Fuselage width = Actual fuselage width (does not include landing gear) measured from outside of cabin.

Table A-3-6.1(b) Method to Determine Helicopter Critical Fire Area and Required Minimum Amount of Water for a Hose Line (AFFF) System

NFPA/ICAO Heliport Category				½ × O.L. of Largest Helicopter[1]		Fuselage Width Tripled[2]		Practical Crital Fire Area		Application Rate [(L/min)/m^2]		Q_1 Water to Control within 1 Min		Q_2 Reserve to Extinguish		Q Total Water to Extinguish
H-1	0 m	<	15.2 m	7.6 m	×	4.6 m	=	34.8 m^2	×	4.1	=	141.9 L	+	100%	=	283.9 L
H-2	15.2 m	<	24.4 m	12.2 m	×	6.4 m	=	78.0 m^2	×	4.1	=	336.9 L	+	100%	=	635.9 L
H-3	24.4 m	<	36.6 m	18.3 m	×	7.3 m	=	133.8 m^2	×	4.1	=	753.2 L	+	100%	=	1090 L

[1]O.L. = Overall length, measured from tip of main rotor fully extended to tip of tail rotor fully extended.
[2]Fuselage width = Actual fuselage width (does not include landing gear) measured from outside of cabin.

To fully appreciate the significance and simplicity of this methodology as a means of determining levels of fire protection, it should be clearly understood that Q_1 is only that minimum quantity of fire-fighting agent required for 1-minute fire control (90 percent extinguishment) of the anticipated practical critical fire area. Therefore, any fire and rescue service cannot be expected to perform an effective rescue effort where equipped with less than the quantity of primary extinguishing agent specified by the volume of Q_1 for the specific airport/heliport category. Furthermore, a fire suppression/rescue mission that is initiated using the required minimum application rate and is continued at that rate, while effectively extinguishing fire or securing unburned fuel within the practical area, ceases operations at the end of 1 minute. In other words, the agent specified by the volume Q_1 is depleted. There is no agent available for mop-up activities, foam blanket repair, or standby protection for continued rescue or salvage activities. Therefore, while the control volume Q_1 provides an operational significance that is critical to the rescue operation, it is, at the same time, limited.

It should therefore be clear that in order to extend an effective fire suppression and rescue operation beyond the initial 1-minute fire control period, an additional volume of foam agent, Q_2, needs to be available. This volume of agent is used to repair foam blanket damage that might be caused by evacuees and rescue workers walking through the foamed areas or by hot surfaces created by the initial fire. Furthermore, Q_2 is needed to extinguish all fire in the practical critical fire area and those fires outside the practical critical area that initially are determined to pose no threat to life. Agent quantity in accordance with Q_2 also provides standby protection before total extinguishment during interior aircraft search operations and for the removal of immobile survivors after fire control. It also is used for securing the fire area during initial aircraft salvage operations immediately after total fire extinguishment. Therefore, an aircraft fire service equipped with only the 1-minute fire control volume represented by Q_1 is expected to assume a significant level of risk. That risk cannot be considered a “calculated risk” unless the manager selecting the reduced agent volume knows the nature of the fire area and the potential hazard involved.

A-3-6.3

The area of application and the duration where using a hose line system is reduced because foam is applied efficiently and directly on the fire by trained personnel.

A-4-1

The design of heliports located on fixed or mobile offshore installations generally is based on landing sites of steel construction. However, in no way should this be construed as a recommendation of steel over other suitable building material.

Appendix B Referenced Publications

B-1

The following documents or portions thereof are referenced within this standard for informational purposes only and thus are not considered part of the requirements of this document. The edition indicated for each reference is the current edition as of the date of the NFPA issuance of this document.

B-1.1 NFPA Publication.

National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.

NFPA *101*, *Life Safety Code*, 1994 edition.

B-1.2 Other Publication.

B-1.2.1 FAA Publication. Federal Aviation Administration, Department of Transportation, Distribution Unit, M-494.3, Washington, DC 20590.

FAA A/C 150/5390-2, *Heliport Design Advisory Circular*, January 4, 1988.

NFPA 422

1994 Edition

Guide for Aircraft Accident Response

1994 Edition

This edition of NFPA 422, *Guide for Aircraft Accident Response*, was prepared by the Technical Committee on Aircraft Rescue and Fire Fighting and acted on by the National Fire Protection Association, Inc., at its Annual Meeting held May 16-18, 1994, in San Francisco, CA. It was issued by the Standards Council on July 14, 1994, with an effective date of August 5, 1994, and supersedes all previous editions.

The 1994 edition of this document has been approved by the American National Standards Institute.

Origin and Development of NFPA 422

Originally a manual, development of NFPA 422M was initiated in 1963, and it was submitted to the Association for adoption at the 1972 Annual Meeting. The document was revised in 1979 and 1984 and the 1989 edition was a reconfirmation of the 1984 edition.

The title for this 1994 edition was changed from *Manual for Aircraft Fire and Explosion Investigators* to the current title. The document was completely revised to provide a framework for the accumulation of data relative to the effectiveness of aircraft accident emergency response services in the application of principles found in the standards and guides developed by the Technical Committee on Aircraft Rescue and Fire Fighting.

This document is intended to assist the committee in collecting significant data that may be utilized to facilitate revisions to the NFPA aircraft rescue and fire fighting documents.

The work of revising this document was accomplished by a task group appointed by the chairman. The following is a list of members of the task group.

Task Group on Aircraft Fire and Explosion Investigators Guide

Ronald O. Wikander, Lockheed Aeronautical Systems Co., GA, Chair; Brian Boucher, Canadian Air Line Pilots Assn., Canada; Booker T. Burley, Hartsfield Atlanta Int'l Airport, GA; B. V. Hewes, Airport Safety Services, GA; Thomas J. Lett, Albuquerque Fire & Safety Assoc., Inc., NM; Lawrence D. Roman, Nat'l Transportation Safety Board, DC; Emory Tate, BDM Int'l, VA

Committee on Aircraft Rescue and Fire Fighting

John F. Rooney, *Chair*
Tucson, AZ

James F. O'Regan, *Vice Chair*
Westboro, MA

Robert J. Donahue, *Secretary*
Massport, MA

Brian Boucher, Canadian Air Line Pilots Assn., Canada
Rep. Canadian Air Line Pilots Assn.

Booker T. Burley, Hartsfield Atlanta Int'l Airport, GA

Ralph Colet, John Russo Industrial Inc.

Robert L. Darwin, U.S. Dept. of the Navy, DC

Charlie L. Duncan, Atlanta Fire Dept., GA

B. V. Hewes, Airport Safety Services, GA

Paul O. Huston, Amerex Corp., AL
Rep. Fire Equipment Mfrs. Assn., Inc.

D. Steve Kiernan, Chubb Nat'l Foam Inc., PA

L. M. Krasner, Factory Mutual Research Corp., MA

Dave Lenz, Oshkosh Truck Corp., WI

Thomas J. Lett, Albuquerque Fire & Safety Assoc., Inc., NM

Rep. NFPA Fire Service Section

D. Robin Maryon, Simon Gloster Saro Limited, England

John J. O'Sullivan, British Airways, England

Davis R. Parsons, Los Angeles City Fire Dept., CA

Gaetan Perron, Dept. of Nat'l Defence, Canada

Robert G. Relyea, ARFF Working Group, TX

Robert E. Reyff, U.S. Air Force, FL

Paul R. Robinson, Kennesaw, GA
Rep. Air Line Pilots Assn.

Bertrand F. Ruggles, U.S. FAA Dept. of Transportation, DC

Joseph L. Scheffey, Hughes Assoc., Inc., MD

John M. Schuster, 3M Co., MN

John X. Stefanki, John X. Stefanki Inc., CA

William J. Wenzel, Schenectady, NY
Rep. Walter Truck Corp.

Ronald O. Wikander, Lockheed Aeronautical Systems Co., GA

Larry E. Williams, Emergency Response Training Academy, Inc., TN

Joseph A. Wright, Federal Aviation Administration Tech Ctr, NJ

Alternates

Fred B. Goodnight, Amerex Corp., AL
(Alt. to P. O. Huston)

Frank M. E. Hughes, British Airways, England
(Alt. to J. J. O'Sullivan)

Robert E. Maxwell, Dept. of Nat'l Defence, Canada
(Alt. to G. Perron)

Thomas E. McMaster, Los Angeles City Fire Dept., CA
(Alt. to D. R. Parsons)

Committee Scope: This Committee shall have primary responsibility for documents on the criteria for aircraft rescue and fire fighting services and equipment, procedures for handling aircraft fire emergencies, and for specialized vehicles used to perform these functions at airports, with particular emphasis on saving lives and reducing injuries coincident with aircraft fires following impact or aircraft ground fires. This committee also will have responsibility for developing aircraft fire investigation procedures as an aid to accident prevention and the saving of lives in future aircraft accidents involving fire.

NFPA 422

Guide for Aircraft Accident Response

1994 Edition

NOTICE: An asterisk (*) following the number or letter designating a paragraph indicates explanatory material on that paragraph in Appendix A.
Information on referenced publications can be found in Chapter 3 and Appendix C.

Chapter 1 Introduction

1-1 Scope.

This document provides a framework for the collection of data that provides information on the effectiveness of aircraft accident emergency response services. This standard applies the principles of those standards and guides developed by the Technical Committee on Aircraft Rescue and Fire Fighting.

1-2* Purpose.

The purpose of this document is to outline a format for a comprehensive emergency response analysis and the collection of significant data that can be utilized to facilitate revisions to applicable NFPA documents.

1-2.1

Part 2 of this guide also may be effectively used to record and critique airport emergency disaster exercises.

1-3 Arrangement.

This guide contains two separate reports that are intended to provide a comprehensive emergency response analysis when completed. These report forms can be photocopied from this guide if they are not available elsewhere.

1-3.1

The forms should be completed by persons with knowledge of the pertinent subject matter.

1-3.2

No obtained information should be released to the news media or to any person unless permission has been obtained first from the chief of the official investigating team. The successful collection of information is related directly to its judicious treatment.

1-3.3

These forms may be used by any person or organization for their internal use. However, when released, copies should be sent to the Committee on Aircraft Rescue and Fire Fighting for entry into the NFPA data bank.

1-4 Units.

This guide uses metric units of measurement in accordance with the modernized metric system known as the International System of Units (SI). The liter unit, which falls outside of but is recognized by SI, is used commonly in international fire protection.

1-4.1

If a measurement value provided in this guide is followed by an equivalent value in other units, the first stated value should be regarded as the recommendation. The equivalent value might be approximate.

1-4.2

SI units have been converted from U.S. values by multiplying the U.S. value by the conversion factor and rounding the result to the appropriate number of significant digits.

Chapter 2 Aircraft Accident/Emergency Response Data

2-1

Reports on incidents and accidents that involve fires should include information on the origin of the fire, the method by which it was spread and fed, the type and effectiveness of extinguishing agents used, and whether any equipment malfunctioned. Methods for fighting fires that follow crashes and for forced entry into burning aircraft have been the subject of much research. All available facts should be reported to improve safety to life.

2-2

It should be noted if escape from the burning plane was successful and whether emergency exits were able to be used or were blocked due to the fire's intensity and location. Information and data should be solicited from flight crew, passengers, and witnesses.

2-2.1

It is important to verify the weather conditions that existed at the time of the fire, particularly the wind direction and velocity. This information, combined with information on the location and use of emergency exits, can provide data on fire spread in the cabin interior.

2-3

Reports should indicate the type of ground fire fighting equipment available and used, including the response time and effectiveness of each responding vehicle, and the quantity and type of extinguishing agents used and left unused. The level of experience and degree of training of fire fighting and rescue personnel also should be reported. The type of clothing worn by personnel involved and the degree of protection provided by this clothing is especially important. Reports should indicate any problems with communications, command and control on the scene, and problems with any emergency plans employed.

2-4

A complete report should be made on the medical findings that result from analysis of the accident. This report should differentiate between injuries and deaths due to fire and those due to impact. Pathological examinations should include toxicological analyses in order to identify all toxic products of combustion. The report also should describe the fire extinguishment and victim care procedures that were used. These reports can be completed by different persons.

2-5

Complete information on in-flight fires is essential in order to improve and develop adequate fire warning and extinguishing systems. The source of the flight crew's discovery of fire in progress and the effectiveness of extinguishment efforts should be determined. A complete, step-by-step description of the procedure used by the crew for extinguishing the fire should be recorded and compared with the approved method listed in the applicable technical manual, flight manual, and flight attendant manual. The voice recorder and the aircraft flight recorder can be most helpful to the investigator in gathering this important information.

2-6

Before completing the aircraft fire and emergency response reports, the following tasks should be completed.

2-6.1

The data collector should become familiar with the overall accident site.

2-6.2

The data collector should determine the location of the responding emergency response services at the time of response and the response routes accessed.

2-6.3

The data collector should first walk through the wreckage area to size up the layout and distribution. This provides a mental picture of the main line of distribution and is helpful for plotting and interpreting witness statements, breakup patterns, etc.

2-6.4

Upon arriving at the accident scene, the data collector should immediately contact the accident investigator in charge. For on-airport accidents, the airport authority or the FAA can provide the location of the investigator in charge. For off-airport accidents, the local enforcement authority should be contacted.

PART I INSTRUCTIONS FOR COMPLETING THE NFPA AIRCRAFT FIRE INVESTIGATION REPORT

The following instructions provide detailed information on how to complete the “Aircraft Fire Investigation Report,” which is reproduced in this guide. Sample information and data and instructions for completion appear in italics.

A. GENERAL

1. Aircraft Data:

a. Type of aircraft (common name or symbol): *Boeing 727*

b. Model no.: *Series 200*

c. Manufacturer of aircraft: *Boeing Company, Seattle, Washington*

d. Type and number of engines: *3*

e. Registration no.: *N304*

f. Name of operator: *OK Airlines*

g. Purpose of aircraft use at the time: *The aircraft was on a charter flight for the World’s Sport Society.*

h. Flight route: *Chicago to Los Angeles via airways*

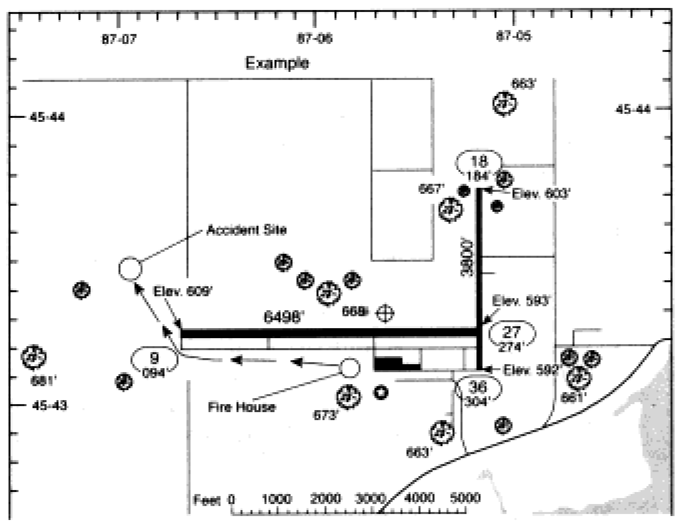
i. Other information: *Provide any additional, appropriate information regarding this aircraft or flight not indicated previously.*

2. Location of Emergency:

a. Provide name of specific airport, if applicable, or city, nearest city, or nearest airport, stating distance factors and, where applicable, compass directions: *1 mile northwest of Burbank Airport, Burbank, California.*

NOTE: In the United States, the National Transportation Safety Board (NTSB) identifies accidents by using the name of the nearest post office.

b. Prepare grid map, including terrain features: *This greatly assists in showing the exact location and helps to determine if the terrain was a factor in the accident. Use the grid map in the fire report. Please note that details of the fire scene are not included in this map but are to be entered later in the report on a separate grid map. In this sketch, show means of access to the accident site, including any perimeter roads around the airport, location of gates, etc. Indicate whether the Rescue and Fire Fighting (RFF) equipment had to travel long distances on public roads, and, if so, sketch the routing.*



3. Time Factors:

a. Date of accident: Day/Month/Year

b. Time (local and Greenwich Mean Time): Hour: minutes (local), Hour: minutes (GMT)

4. Type of Aircraft Accident: *There are eight basic types of accidents as far as the responsibilities of the aircraft fire investigator are concerned.*

a. Crash, no fire: *It is important for the investigator to determine why no fire occurred. What set of circumstances caused this crash without also causing a fire? A study of procedures that were used can be of benefit in future crashes.*

b. Crash, immediately followed by fire: *This type of accident is the opposite of item 4.a., but the object of the investigation is the same. What procedures were used?*

c. Crash, followed by fire but with delay in ignition (time interval): *What caused the delay in the ignition, and what procedures could have further delayed or prevented the ignition?*

d. Fire in air, fire extinguished in flight: *The cause of the fire should be determined, and the procedures used to extinguish the fire. How can these procedures be improved? Did the crew act rapidly enough?*

e. Fire in air, followed by crash and fire: *Crew members seldom survive this type of accident, and careful examination of the wreckage is necessary to determine the cause and location of a fire in the air. Examination of various components of the aircraft fire extinguishing system indicates the extent to which the extinguishing system was used and the procedures were* *completed. Remember to check the positions of components of other systems on the fire extinguishing checklist. It is possible that the procedure for manipulation of the fire extinguishing controls was positioned low on the checklist so that the crew did not have time to perform this function. Can the procedure be shortened? Why was the procedure unsuccessful in extinguishing the fire?*

f. Fire on the ground (no crash): *The cause of the fire should be determined to help prevent future fires of this type. The fire sequence should be examined carefully to determine if it is possible to reduce the time needed to extinguish a fire, the time needed to detect a fire, and the time needed to isolate a fire.*

g. Fire inside hanger (no crash): *The cause should be determined to aid in developing prevention techniques. Once the causal factor has been established, efforts to prevent this type of fire can be successful; however, since the cause of this type of fire usually is traced to human behavior, the procedures used and their effectiveness should be noted carefully. Can the procedures be made more effective?*

h. Fire—other (specify): *This section addresses any other type of aircraft accident. The causal factor should be determined, and the extinguishing procedures used and the extent to which they were successful should be identified. Can they be improved?*

i. In-water accident: *Determine the cause of the accident. It is important to describe the tactics, strategy, and equipment utilized to suppress fire and accomplish rescue in these circumstances. Much can be learned from this information.*

j. Other aircraft ground incidents: *It is important to describe other emergencies that necessitate an Aircraft Rescue and Fire Fighting (ARFF) response. Many times the prompt response of the ARFF prevents major aircraft damage and loss of life, and significant new response techniques are developed as a result.*

5. Flight Factors: *Observation of various flight factors prior to, during, and subsequent to initiation of an aircraft fire can supply information that leads to possible changes in procedures, structures, etc., that might prevent reoccurrence. Some pertinent flight factors include:*

a. Crash at takeoff: *Indicate the point in the takeoff roll at which the crash occurred. Had power been reduced? What was the configuration of the flaps, gear, etc.?*

b. Crash immediately after takeoff: *Indicate the approximate maximum altitude reached. Record the configuration of the flaps, gear, etc. Had power been reduced? What were the changes in the heading (if any) of the aircraft? Was any smoke or flame emitting from the aircraft? If so, from where and at what point in time?*

c. Aircraft in flight, power stall: *Was the aircraft involved in any abrupt pull-up? Was power still being applied?*

d. Aircraft in flight, explosion in air: *Was there any explosion while in the air? If so, when? Take care to differentiate between explosions and other sounds. A breaking spar can sound exactly like an explosion.*

e. Aircraft in flight, fire in air: *If a fire during flight is suspected, what indications, such as smoke or flame, are present? From what portion of the aircraft? The location of the smoke emissions from an aircraft often can provide a valuable clue to that checklist procedure last performed by the crew before fire occurred. What color and how intense is the smoke? Describe the color of the smoke as it relates to everyday items (e.g., white as a bed sheet, gray as newsprint, etc.).*

f. Aircraft in flight, structural failure: *In which phase of flight was the aircraft (takeoff,* *initial climb, cruise, etc.)? Which structure failed and when? In what manner? Was fire present? Did the fire occur before or after the structural failure?*

g. Collision with other aircraft while airborne: *In this situation, the main focus of attention should be the relative angle between the two aircraft as they approached each other.*

h. Collision with structure: *At what phase of flight did the collision occur (takeoff, initial climb-out, landing, etc.)? At what altitude above the ground did the collision occur?*

i. Collision with ground: *In which phase of flight was the aircraft? What was the angle of impact? Describe the type of terrain and surface characteristics (e.g., ditches, embankments).*

j. Crash while landing: *Did the crew give any warning of any unusual condition? Was any unusual condition evident from the ground? At what phase of the landing did the collision occur (e.g., prior to touchdown, during rollout, during taxi, etc.)?*

k. Crash while making emergency landing: *What were the indications regarding the type and nature of the emergency? In what type of terrain was the landing attempted? In what phase of the landing did the crash occur?*

l. Other:

6. Weather Factors:

a. General weather conditions: *Rain, fog, ice, snow*

b. Surface visibility, miles: *Runway visibility (RVR)*

c. Wind direction and velocity in knots:

d. Ambient temperature and dew point in °F or °C: *Specify measurement used.*

e. Ice, snow, fog, dry, wet:

f. Visibility distance:

B. FIRE FACTORS

1. Aircraft Fuel (Class B Fire):

a. Estimated amount of fuel on board at time of accident: *The quantity of fuel carried by the aircraft at the time of the incident/accident and an accounting of its status during and after the time of impact (if any) and fire (if any) are important in evaluating the effectiveness of the fuel tank construction and installation in minimizing fire hazard factors. Provide the quantities in gallons, pounds, kilos, or liters, specifying the unit used.*

b. Describe type of fuel spill and effect of terrain and soil conditions on fuel spill: *The dimensions of the fuel spill area in sq ft at time of ignition should be estimated, and the sequence of fire growth should be recorded from that time of ignition. This should include the rate of fuel leakage from tanks or broken fuel lines and the rate of growth of fuel spill area. (See NFPA 407, Standard for Aircraft Fuel Servicing, Section 3-2, for spill prevention and control.) Did the scope of the terrain affect fuel runoff?*

2. Other Flammable Liquids (Class B Fire): *Yes/No.*

Comments: Describe the part that engine oil, hydraulic fluid, alcohol, etc., played in the fire (pertinent only when original combustible or primary amount of fuel is involved): *It is common knowledge that other special purpose liquids carried aboard aircraft are not only combustible but can be destructive to foams that are likely to be used to extinguish the main fuel fire. Although the quantities of these liquids are small in comparison with the quantity of fuel load, their presence should be treated as a clue to any effectiveness deficiency in the extinguishing agents used.*

3. Combustible Metals (Class D Fire): *Yes/No.*

Comments: Describe the role of combustible metals as possible ignition source or continuing source of ignition (list types of metals involved): *What was the effect on fire control? Magnesium and titanium are the only metals likely to be encountered as factors in an aircraft fire. Metals usually are not the cause of large fires; however, they can create severe problems in a fire situation, since not only are they difficult to extinguish, but the usual agents, water and water-containing agents (e.g., foam), aggravate and often spread the burning metal. The metals themselves rarely self-ignite, but friction sparks resulting from their contact with the runway surface usually ignite fuel from any leaks in their vicinity. Metal fires usually are due to prolonged heating by the flames of liquid fuel fires or are the result of the friction of metals in contact with the runway. Titanium fires rarely occur.*

4. Ordinary Solid Combustibles (Class A Fire): *Yes/No.*

Comments: Baggage, cargo, personal effects, cabin interior furnishings, etc.: *Describe the role of solid combustibles as the original ignition source, the original combustible involved, or in terms of their effect on fire control. Fires burning in ordinary materials of construction, such as wood, cotton, rubber, synthetics, etc., are Class A fires. These fires normally are extinguished by water or foam and pose no special problem, except that they might be hidden and inaccessible to the fire fighter and, therefore, can constitute a constant reignition point for the flammable vapors.*

NOTE: Special attention should be given to radioactive substances carried in cargos under restricted conditions. See NFPA 402M, *Manual for Aircraft Rescue and Fire Fighting Operations,* Appendix C.

5. Other Combustibles Not Part of Aircraft: *Yes/No.*

Comments: Trees, grass, brush, vehicles, structures, etc.: *Describe the role of other combustibles as the original ignition source, the original combustible involved, or in terms of their effect on fire control.*

6. Oxygen Involvement: *Yes/No.*

7. Hazardous Materials/Dangerous Goods: *Yes/No.*

Comments: *Include any hazardous materials carried on the aircraft and their effect on the fire. Etiological factors should be covered in Part II.*

C. IGNITION SOURCE

1. General Location of Probable Original Ignition Source: *Ignition factors can be divided into four basic groups, as follows:*

a. Impact — frictional sparks, striking power lines, etc.: *The source of original ignition quite frequently is other than the aircraft itself. Ignition can result from a friction spark that occurs on impact or possibly from power lines or the landing area lighting system. When conducting investigations, a serious effort should be made to determine the cause of ignition. Each aircraft accident exhibits evidence of several ignition sources and usually more than one fire factor. The sources and factors of greatest concern are those that cause sustained fire progression. A close examination of the ground that runs from the aircraft back along the skid path, and even beyond the point of initial ground contact, is necessary to determine the point at which ignition occurred. This also helps determine whether fire was present prior to actual* *touchdown. Discoloration or charred material found in this area should be examined closely to attempt to determine the type of material burned and its possible location relative to the construction of the aircraft. Such material might consist of cabin furnishings, gear components, engine components, etc. Unlike structural buildings, where fire loads are somewhat static, the original ignition source in aircraft fires is not found necessarily in the areas where the most severe burning occurs. Information included in the report should describe the point of sustained ignition in relation to its position on or in the aircraft.*

b. Power plants: *In aircraft accidents where impact forces are extremely excessive, the aircraft power plants generally provide the initial ignition of aircraft fuel loads. For this reason, every attempt should be made to determine the damage to, as well as any movement of, the engines during and after initial impact. Ignition generally takes place when engines become torn loose, severing fuel and electrical power lines. This is especially true of the turbine engine, as it remains extremely hot internally and continues to rotate for a period of time after impact.*

c. Aircraft electrical circuits: *The next most common fire ignition results when electrical lines are severed in a fuel vapor atmosphere. Every effort should be made to examine broken wires and circuit breaker panels to discover possible causes of ignition, keeping in mind that there should be a source of flammable vapor or exposed combustibles in the area of the arcs, sparks, or heat if a fire was caused by such an ignition source. Examination of aircraft batteries also should be included in this investigation.*

d. Electrostatic sparks: *These often can be the cause of the original ignition source, since the aircraft itself, or portions of the aircraft that become separated during impact, builds up an electrostatic charge while moving through the air and might discharge this residual energy upon contact with the ground.*

e. Other sources of ignition not covered previously:

2. Progress of the Fire:

a. Describe the progress of fire from ignition through extinguishment: *Once the point of sustained ignition is determined, a close examination of the burn pattern, together with a study of the aircraft construction, should provide a fairly clear picture of how the fire propagated prior to fire extinguishment action. In many cases, the fire fighting efforts themselves cause fire extension in unusual patterns. These patterns generally can be distinguished from normal fire progression by the presence of extinguishing agent residue in the burn deposit. Note that normal fire behavior causes upward extension of the fire more rapidly than it causes lateral extension. Most materials, when burned or heated, become subject to air currents, and a close examination of the burn area provides an indication of fire travel by the manner in which the charred material is curved. At this point in the investigation, it is especially helpful to have an understanding of the temperature at which different metals melt or support combustion. It also is important to understand that fire can progress by radiation, convection, and conduction. Due to the aircraft construction, fire progression usually occurs by all three of the above methods. The most accurate account of fire progression usually can be obtained from eyewitnesses; however, during questioning, it is important to remember that each witness is likely to provide a different version of any given circumstance. No assumptions should be made until statements from several eyewitnesses have been received. Reported information then should be based on those facts most strongly supported by all of the accounts. When filling out the report form, chart the fire progression as closely as possible from the time of initial touchdown or sustained ignition. The progression should be recorded in minutes and seconds. This provides a more complete* *accounting of the fire progression. Also, attempt to determine any unusual problems encountered during fire extinguishment operations.*

b. Describe path and speed of flame spread; also the effect of structural breakup on flame spread; effect of open exits on flame spread; identify who opened exits and when they were opened: *These items are somewhat self-explanatory, and the answers can be obtained during the normal course of the investigation. Interrogation of survivors and eyewitnesses is the most reliable source of this information, but care should be taken in evaluating this information from individuals who are closely involved. Where possible, the most satisfactory method of determining time factors for specific conditions is to have persons furnishing factual information recreate their actions, as most people lose the awareness of time during emergency situations. If possible, survivors should recreate their actions during the accident while inside an aircraft of identical type and configuration. In reporting on this phase of the investigation, it is best to furnish a sketch of the aircraft and identify exits and other points of reference by use of a numbering system or other suitable means.*

c. Describe extent and length of time of fuselage survivability after impact: *This factor is subject to many variables, such as toxic gases, extent of carbon monoxide contamination, percentage of oxygen in the cabin, and temperature gradients. A complete laboratory analysis should be done on burn tests of the cabin interior materials to determine the toxicity of fumes. It is especially helpful to furnish a diagram of the cabin configuration showing those seats occupied at the time of impact. The diagram also should show the location of any fatalities and indicate those found in their original seat location. The survivors and flight attendants are the best source of this information, and an attempt should be made to determine how much time elapsed after impact before the last known survivor evacuated the aircraft. Investigation of fire origin and progression through the cabin also are very helpful in determining this time lapse. Examination of the items that follow will be beneficial in determining the above factors.*

(1) Inspection of metal parts: *A close investigation of metal parts involved in the fire area provides information on the severity and temperature of the fire. A basic knowledge of melting temperatures of various metals is necessary to establish temperatures. Since most aircraft metals are lightweight, they become subject to air currents when they are heated or reach the fluid state.*

(2) Fuel odors: *During the investigation, check all areas of the aircraft for residual fuel odors to determine the extent of fuel spread. This is especially important in the baggage and cabin areas. Regardless of the extent of burnout, if fuel was present, the charred remains will have produced some trace of fuel odor.*

(3) Pressurized containers: *Many types of pressurized containers can be found in the personal effects aboard the aircraft as well as in the ordinary furnishings in the cabin area. Where pressure has been released during fire, unusual burn patterns can be detected. These provide an indication of free-burn areas as well as excessive temperatures that can cause exterior venting.*

(4) Oxygen systems: *Both fixed systems and walk-around oxygen bottles contribute greatly to cabin burnout. These systems should be located and identified before a full appraisal of the fire behavior is reported.*

(5) Smoke deposits: *During the investigation, various types of smoke and ash deposits* *will be encountered. Any unusual deposits of these materials should be inspected carefully and analyzed to determine the type of material that caused the burn. Foreign material deposits in these areas also should be noted.*

D. AIRCRAFT SAFETY SYSTEMS

1. Did aircraft have any fixed fire extinguishing systems? *All transport category aircraft, as well as some light twin aircraft, have such systems. Most single-engine types do not.*

2. What type of system?

3. Specify extinguishing agent employed: *Most modern aircraft are equipped with bromotrifluoromethane (halon 1301) systems, which discharge by remote control from the cockpit into the fire zone of each engine by selection. Some aircraft also discharge agent into baggage bins, but most do not. Other agents that might be used are carbon dioxide (CO_2), chlorobromomethane (CB or CBM), or bromochlorodifluoromethane (halon 1211-BCF). The investigator should obtain all necessary details of the system installed from the fire extinguishing equipment manufacturer.*

4. Was it used? What effect did it have on fire? *If possible, determine sequence of events and the answers to these questions from conversation with crew. Sequence should include the time from fire alarm or detection to discharge of agent and the effect of agent on fire. Was entire quantity of airborne agent used on fire? If fire continued, indicate time from discharge to landing or impact. Describe airborne progression of fire. If crew is not available, determine from examination of aircraft or remains the position of the fire discharge controls, whether or not extinguishing agent cylinders are empty, etc.*

5. Were aircraft hand-operable fire extinguishers available? Were they used?

6. State effectiveness: *These questions apply only to fire originating in a cabin or in accessible baggage bins.*

7. Did the aircraft have fire alarm and detection equipment installed?

8. What type? Did it operate?

9. Other information: *Any other information pertinent to the aircraft fire detection and extinguishing system.*

E. EMERGENCY NOTIFICATION

1. How long after the accident occurred was it discovered? *If there was uncontrolled ground fire, the investigator's job is made more difficult by destruction of possible evidence and the obscuration and masking of existing evidence. If exact time is not available, a close approximation later in the investigation helps significantly in determining burn times and effect on the evidence.*

2. Who discovered the accident? *The time lapse between the occurrence of an accident and its discovery is a factor of some importance to the investigating team. Many aircraft accidents are discovered after it is too late. The reasons vary: weather conditions, aircraft out of fuel, isolated areas, and loss of communication with the aircraft. The discovery of an accident by other aircraft notification or by survivors ultimately can be of great value to the investigator.*

3. Who dispatched the fire alarm? *Agency that ordered ARFF equipment to respond.*

4. How was the fire alarm transmitted? *Box, telephone, radio, observed, other (specify). It is important for the investigator to find out from reliable sources who initiated the alarm and how it was transmitted. Many airports have a mutual aid agreement with local fire authorities whereby alarms are transmitted by a "hot line" connected directly to the fire department alarm station for use in the event that outside help is needed by the airport crash and rescue crew.*

5. Was location of accident accurately described? *If not, indicate the reason and describe the effect of any related delay in fire and rescue service. The investigator should be informed of the accuracy or inaccuracy of the original description of the accident location. In cases where an inaccurate location has been provided, valuable response time has been lost. It is then necessary to investigate the reason for the delay in the response.*

6. Consequences of erroneous response information:

7. What were the fire and evacuation conditions at the time of arrival of the rescue and fire fighting equipment? *The fire and evacuation conditions at the time of the arrival of the rescue units are highly significant in the final analysis of the accident. These conditions can indicate the extent of fire, complete engulfment by fire, presence of interior or exterior fires, type of odors, smoke, and evacuation status of passengers. Were passengers evacuating, not evacuating, or was evacuation complete on arrival of rescue equipment?*

8. Time factors: *Time factors should be determined as precisely as possible from the records, flight crew, fire department, air traffic control tower, and Air Traffic Control (ATC), etc. After analysis, the investigator should be able to determine the effectiveness of each phase of the operation. Include response time of ARFF vehicles, from alarm to arrival at the scene, and number of vehicles with VHF communications. Also include response interference factors (e.g. weather, traffic, terrain) and those that affected the response time of the ARFF vehicles such as: weather, distance from fire house, terrain, and access roads.*

9. Remarks: *Include all conclusions drawn by the data collector after analysis of the detection and alarm system used and the time factors involved. If any time factors seem implausible, the data collector should request a simulation or rerun.*

F. AIRCRAFT RESCUE AND FIRE FIGHTING (ARFF) SERVICES

1. Vehicles and Manpower Table. *This table should be filled out carefully by the investigator working in coordination with the fire department. It provides information on the effectiveness of particular vehicles and the physical details of the operation and is useful not only in assessing effectiveness for the particular fire but serves as documented experience for study by all RFF services. Make certain to note condition of each vehicle in the "Remarks" section. Note any injuries to RFF personnel during this operation as well as details of the use of any airport-based medical vehicles. The quantities provided in tables should be expressed in national units of measure of state involved.*

2. Fire Extinguishing Agents Used and Techniques Employed: *This table should be filled out carefully by the investigator working in coordination with the fire department. This table is used to assess the overall effectiveness of the fire department by determining quantities of agents used, discharge rates and time, and order of agent use. In the "Remarks" section, note any effect* *agents have had on one another. Note specifications and type of agents used and the quality of agent produced. Fire fighters on duty during the operation should be questioned regarding any deleterious effects on the foam blanket due to any other agents used. The quantities provided in tables should be expressed in national units of measure of state involved.*

a. *In the past, agent quantities were determined from fire ground tests and previous experience, since detailed accident data was unavailable.*
In order to justify the agent quantity formula, $Q = Q_1 + Q_2 + Q_3$, *it is essential that the following data be available:*

Q_1 *- water quantity for control of the fire*

Q_2 *- water quantity used for extinguishment*

Q_3 *- water used by handlines, water used for maintenance (overhaul) operations.*

3. Fire Fighting Operations: *Describe conduct of fire fighting operations after arrival of equipment. After questioning the fire department, reconstruct the operational details in chronological order. Briefly describe the extent of the blaze, effect of the fire fighting operation, start of evacuation, and completion of rescue and control of the fire situation. If the fire attack was interrupted by a lack of replenishment water, note the reason for the delay. Include a description of problems encountered and lessons learned.*

a. Training: It is important to ensure adequate and proper training by maintaining records on the type and frequency of training and the most recent training evolution employing hot drills, cabin interior drills, and aircraft pre-fire planning. Lack of sufficient training is a significant factor in the improper use of existing ARFF equipment.

b. Clothing: The type of protective clothing utilized for fire suppression is significant, since NFPA 1500, *Standard on Fire Department Occupational Safety and Health Program*, mandates a minimum level of personal protective equipment for ARFF.

c. Self-Contained Breathing Apparatus (SCBA): Recording the use of SCBA and the type utilized establishes statistics that define the levels of personal protective equipment used to suppress ARFF fires.

4. Grid Map of Accident: *Sketch the details suggested in the fire report on a separate sheet of paper. When satisfied that all details are included, transfer the sketch to the grid map. In the explanatory remarks, explain all details of the diagram that are necessary.*

G. HUMAN FACTORS. *It is vitally important when analyzing an aircraft accident involving fire to obtain as much information as possible on the occupants of the aircraft. Improved aircraft structures and rescue techniques can result. Therefore, as many details as possible should be obtained by investigators. The coordinated effort of the entire investigation team should be used in this area.*

1. Personnel Table: *After consultation with those who participated in the rescue of personnel, the investigator should fill out this table carefully. If possible, a seating arrangement showing the location of passengers and crew prior to the accident (including gender and whether child or adult) should be obtained.*

2. Number of Casualties: *The investigator should create a seating arrangement chart indicating the status of passengers and crew during and after the accident, e.g., injury, burns,* *fatality, (provide cause, e.g., burns, asphyxiation, impact), escaped unaided, rescued by fire and rescue personnel.*

3. Describe Evacuation, Number of Rescue Personnel, Exits Used, Break-in Areas Used: *Extensive questioning of flight crew and passengers should help the investigator in this description. Include the extent of briefing and preplanning, if known.*

a. *Had occupants begun evacuation or were they waiting to be rescued?*
b. *Had flight crew been able to complete emergency shutdown drills?*
c. *Were passengers or crew able to operate escape hatches satisfactorily?*
d. *Was sufficient marking and lighting available to facilitate evacuation?*
e. *Describe in detail any difficulties encountered in evacuation.*

4. Time Required to Accomplish Rescue and Removal of Occupants:

a. *Did occupants respond to orders from rescue crews?*
b. *Which emergency exits were used during evacuation? Did they function properly, or were they damaged by impact or fire?*
c. *Were aircraft crew able to assist in the rescue? If so, to what extent?*
d. *How many persons used each means of egress?*

5. Time Required to Control Fire? Time Required to Extinguish Fire? *Describe in detail if passenger and crew evacuation delayed extinguishing of fire. Smoldering and small spot fires not affecting rescue should not be included in this time factor.*

Copies of each report should be sent to the appropriate government authorities involved in the investigation.

When released by these authorities, reports should be sent to the following organizations:

International Civil Aviation Organization
1000 Sherbrooke Street, W
Montreal, PQ, Canada H3A 2R2

Fire Analysis Department
National Fire Protection Association
1 Batterymarch Park
P.O. Box 9101
Quincy, MA 02269-9101 U.S.A.

Other concerned qualified authorities such as the U.S. Air Force, U.S. Navy, U.S. Flight Safety Foundation, etc.

NATIONAL FIRE PROTECTION ASSOCIATION
AIRCRAFT FIRE INVESTIGATION REPORT

Report # **Date of Report**

A. GENERAL

1. Aircraft Data

a. Type of aircraft ______________________

b. Model no. ______________________

c. Manufacturer of aircraft ______________________

d. Type and number of engines ______________________

e. Registration no. ______________________

f. Name of operator ______________________

g. Purpose of aircraft use ______________________

h. Flight route ______________________

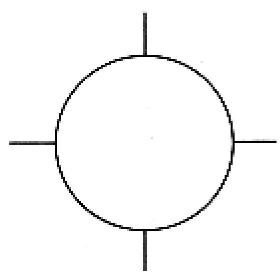
i. Other information ______________________

j. Other ______________________ Name of operator ______________________

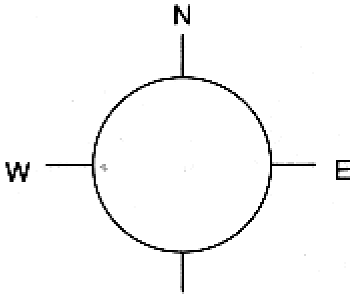
2. Location of Emergency

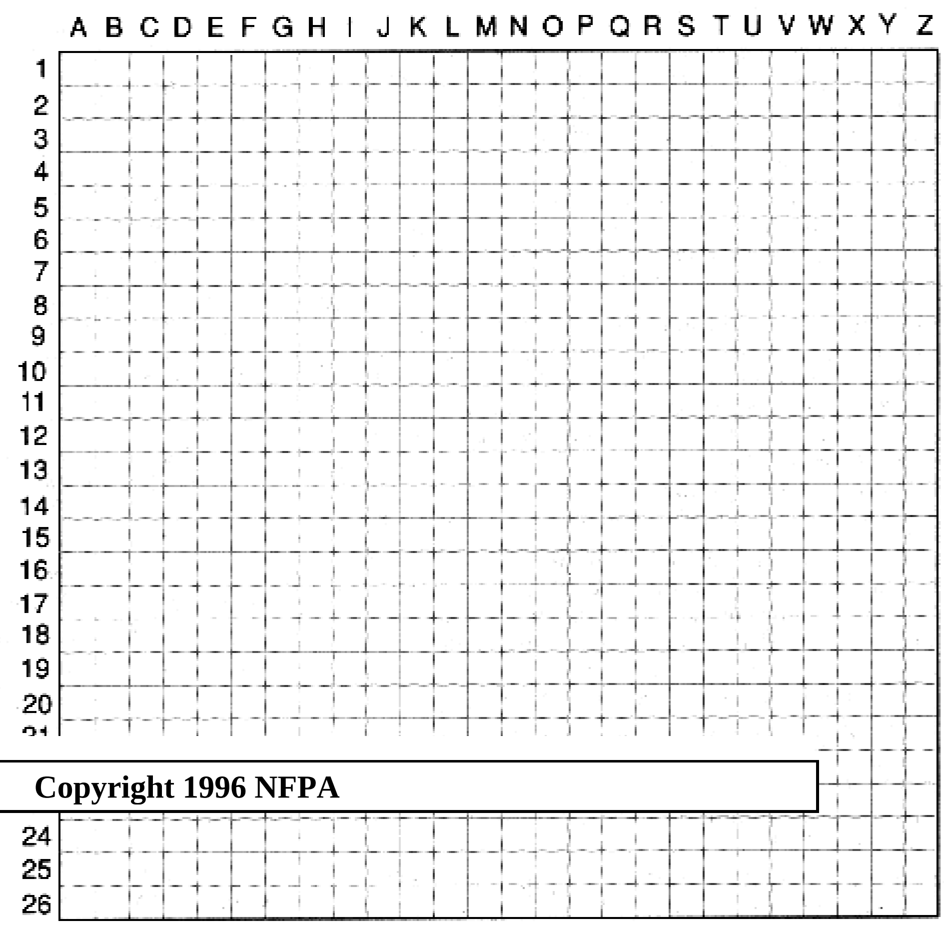
a. Provide name of specific airport, if applicable, or city, nearest city, or nearest airport, stating distance factors and, where applicable, compass directions.

b. Prepare grid map showing location of the accident site in relation to the fire station, the access route taken, and any significant features, such as runways, taxiways, aprons, roads, and water area. Include relationship of crash site to city or airport.



Indicate grid compass direction





Compass direction
Indicate wind direction with arrow
State wind velocity

3. Time Factors

a. Date of accident ____________________

b. Time—Local ______________________

4. Type of Aircraft Accident (check the appropriate items)

a. Crash, no fire ______________________________

b. Crash, immediately followed by fire ______________________________

c. Crash, followed by fire but with delay in ignition ______________________________

Time interval __________________ minutes

d. Fire in air, fire extinguished in flight ______________________________

e. Fire in air, followed by crash and fire ______________________________

f. Fire on the ground (no crash) ______________________________

g. Fire inside hangar (no crash) ______________________________

h. Fire—other (specify) ______________________________

i. In-water accident ______________________________

j. Other aircraft ground incidents ______________________________

5. Flight Factors (check the appropriate items)

On airport ______________ Off airport ______________

a. Crash at takeoff ______________________________

b. Crash immediately after takeoff. Altitude obtained ______________________________

c. Aircraft in flight, power stall ______________________________

d. Aircraft in flight, explosion in air ______________________________

e. Aircraft in flight, fire in air. Designate origin ______________________________

f. Aircraft in flight, structural failure. Designate structure ______________________________

g. Collision with other aircraft while airborne ______________________________

h. Power on, collision with structure ____________ Type of structure ____________

i. Power on, collision with ground ______________ Type of ground ______________

j. Crash while landing (runway) ______________________________

k. Crash while making emergency landing (off runway) ______________________________

Type of terrain ______________________________

l. Other (specify) ______________________________

6. Weather Factors

a. General weather conditions ______________________________

b. Surface visibility ______________ miles/feet

c. Wind direction ____________________ Wind velocity/knots __________________

d. Ambient temperature __________ °F ______ °C Dewpoint ________ °F ______ °C

e. Ice ________ Snow ________ Fog Dry __________ Wet __________

f. Visibility distance ______________________________

B. FIRE FACTORS

1. Aircraft Fuel (Class B Fire)

a. Quantity of fuel ____________ Type of fuel ____________

b. Describe type of fuel spill.

(1) Dimensions ______________________________

(2) Rate of fuel leakage ____

(3) Terrain ____

(4) Soil conditions ____

2. Other Flammable Liquids (Class B Fire) Yes ____________ No __________

Comments: ____

____

____

3. Combustible Metals (Class D Fire) Yes ____________ No __________

Comments: ____

____

____

4. Ordinary Solid Combustibles (Class A Fire) Yes ____________ No _________

Comments: ____

____

____

5. Other Combustibles Not Part of Aircraft Yes ____________ No __________

Comments: ____

____

____

6. Oxygen Involvement Yes ____________ No __________

Liquid __________ Gaseous __________ Solid (Generator) ____________

7. Hazardous Materials/Dangerous Goods Yes ______________ No __________

Type and location ____

Comments: ____

____

____

C. IGNITION SOURCE

1. General Location

a. Impact ____

b. Power plants ____

c. Aircraft electrical circuits ______________________________________

d. Electrostatic sparks ____

e. Other sources ____________________

2. Progress of the Fire

a. Describe the progress of the fire from ignition to extinguishment. ____________________

____

____

b. Describe the path and speed of flame spread; also the effect of structural breakup on flame spread, effect of open exits on flame spread; identify who opened exits and when they were opened. ____________________

____

____

c. Describe the extent and length of time of fuselage survivability after the impact.

(1) Inspection of metal parts ____________________

(2) Fuel odors ____________________

(3) Pressurized containers ____________________

(4) Oxygen systems ____________________

(5) Smoke deposits ____________________

D. AIRCRAFT SAFETY SYSTEMS

1. Did the aircraft have any fixed fire extinguishing systems? ____________________

2. What type of system? ____________________

3. Specify extinguishing agent employed ____________________

4. Was it used? ____________________ **What effect did it have on the cabin, lavatory, cargo, or engine fire?** ____________________

____

5. Were aircraft hand-operable fire extinguishers available? Were they used? ____________________

6. State effectiveness ____________________

7. Did the aircraft have fire alarm and detection equipment installed? ____________________

8. Which type? ____________________

Did they operate? ____________________

9. Other information ____________________

E. EMERGENCY NOTIFICATION

1. How long after the accident occurred was it discovered? ____________________

2. Who discovered it? ____________________

3. Who dispatched the fire alarm? ____________________

4. How was the fire alarm transmitted? ____________________

Box ________ Telephone ________ Radio ________ Observed ________ Other __

5. Was the location of the accident accurately described? ____________________

6. If not, indicate the reason and describe the effect of any related delay in the response of the ARFF. ____________________

7. What were the fire and evacuation conditions at the time of arrival of the ARFF?

____

8. Time Factors

a. If emergency preannounced, from announcement to touchdown (impact), ____________ minutes

b. If emergency not preannounced, from accident/incident to alert of the ARFF services, minutes

c. From alert to the arrival of the major vehicles, ____________ minutes

d. From arrival of the ARFF to fire under control, ____________ minutes

e. From arrival of the ARFF to rescue operations commencing, ____________ minutes

f. From arrival of the ARFF to rescue operations terminated, ____________ minutes

g. From arrival of the ARFF to extinguishment of the fire, ____________ minutes

h. From extinguishment of fire to return to service, ____________ minutes

i. List any factors that affected the response time of the ARFF ____________

____

9. Remarks ____________________

____

____

____

F. RESCUE AND FIRE FIGHTING (ARFF) SERVICES

1. Vehicles and Manpower

a. Were any vehicles out of service at the time of accident? ______

List type and reason for lack of availability

(1) ______

(2) ______

(3) ______

VEHICLE AND STAFFING TABLE

		Vehicle 1	**Vehicle 2**	**Vehicle 3**	**Vehicle 4**	**Vehicle 5**
Brand Name and Manufacturer						
Date of Procurement						
Model/Year of Manufacture						
Agent Capacity Check One Gallons ______ Liters ______	Foam					
	Water					
	Dry Chem.					
	Halon					
	Other					
Agent Discharged Check One Gallons ______ Liters ______	Foam					
	Water					
	Dry Chem.					
	Halon					
	Other					
Manpower Assigned						
Number of Turrets						
Turret Flow Rate(s) and Pattern	1					
	2					
Time Vehicle Dispatched						
Response Time to Scene						
Distance Traveled						
Time Returned to Service						
Terrain Conditions	Ice					
	Mud					
	Snow					
	Steep Slopes					
	Sand					
	Other					
Communication Equipment	Radio					
	Cellular Phone					
	Fax					

Remarks: ______

______

______

2. Fire Extinguishing Agents Used

Table 2(a) Total Agents and Quantities Applied

Check One: Gallons ________ Liters ________

Type	Control - Q1	Extinguish - Q2	Handlines Overhaul - Q3
Dry Chemical			
Halon			
Foam			
Other			

Table 2(b) Handline Utilization

	Number of Lines	Size of Lines	Flow Rate Hoseline(s) Check One GPM _____ LPM _____			Handline Size Hoseline(s)			Nozzle Type Hoseline(s)			Manpower Hoseline(s)		
			#1	#2	#3	#1	#2	#3	#1	#2	#3	#1	#2	#3
External Use														
Interior Use														

3. Fire Fighting Operations

Were vehicles replenished with water? No ______________ Yes ____________

Source: Tankers ______ Hydrants ______ Drafting ______ Relay pumping ______

Describe details or resupply operation: ____

____

Were vehicles replenished with foam?No ______________ Yes ____________

Source: 5-gallon cans ______ Barrels____ Tanker on-site ______ Tanker at firehouse ________________

Was agent replenishment a factor that impaired the fire suppression operation? If yes, explain ____

____

Describe the fire fighting strategy and tactics in detail ____________________________

____

Problems encountered ____

Lessons learned and verified by experience ____________________

a. Training

(1) Training to NFPA 1001, *Standard for Fire Fighter Professional Qualifications*, and NFPA 1003, *Standard for Airport Fire Fighter Professional Qualifications* ____________________

(2) Date of last live fire ____________________

(3) Date of last cabin interior drill ____________________

(4) Date of last aircraft pre-planning exercise on affected aircraft ____________________

b. Clothing

(1) Type of protective clothing used.

(NFPA 1976, *Standard on Protective Clothing for Proximity Fire Fighting*)
Proximity ____________________

(NFPA 1971, *Standard on Protective Clothing for Structural Fire Fighting*)
Structural ____________________

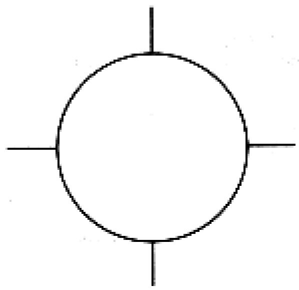
c. Self-contained breathing apparatus (SCBA)

(1) Which type? ____________________

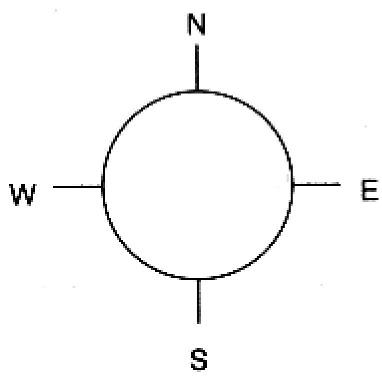
(2) Was it used? ____________________

4. Grid Map of the Accident

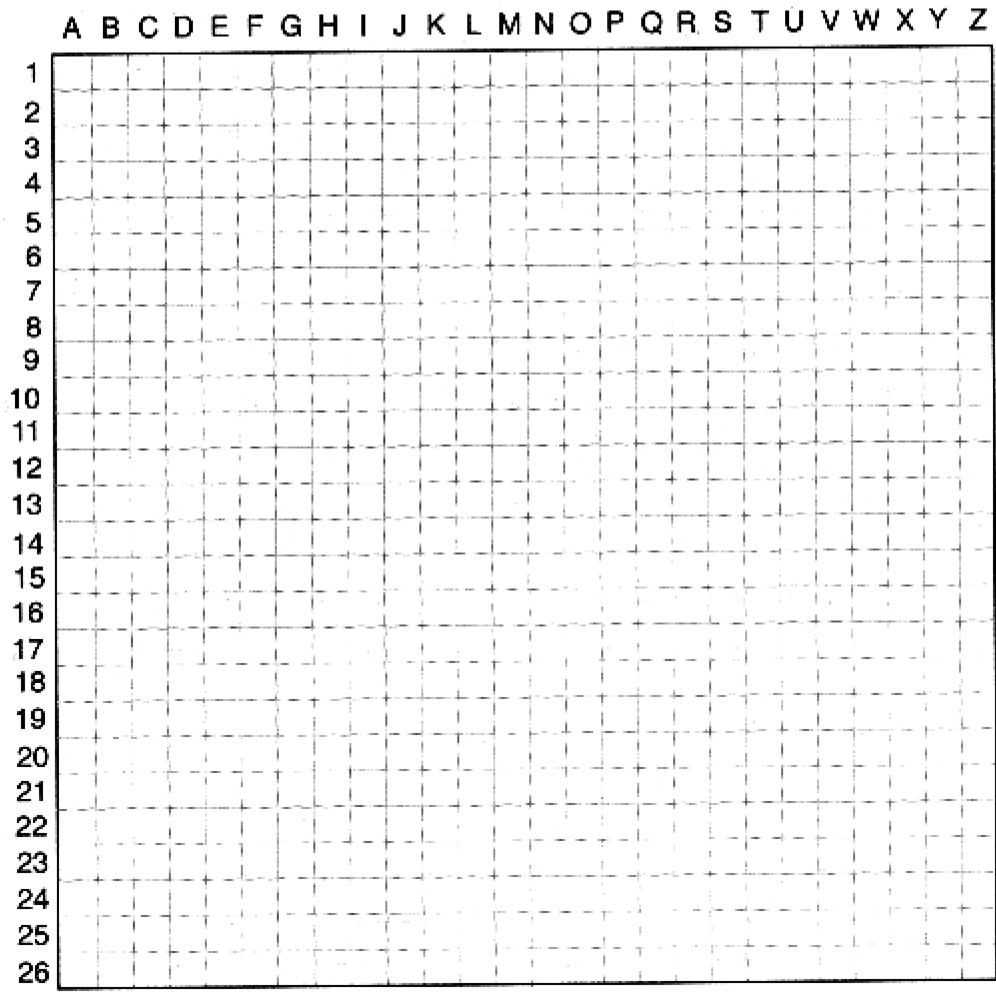
a. Draw a diagram showing the positioning of the ARFF equipment in relation to the aircraft and including significant features such as fuel spills, escape routes, unusual terrain, water supplies, and buildings.



Indicate grid compass direction



Compass direction
Indicate wind direction with arrow
State wind velocity



Explanatory Remarks

G. HUMAN FACTORS

1. Personnel Table

Occupants	Total on Board	Evacuated Unaided	Extricated	Medical Priority 1	Medical Priority 2	Medical Priority 3	Fatalities
Passengers							
Crew							
Other							

2. Number of Casualties

a. Number who died as a result of this accident? ____________________

b. Number who died as result of burns? ____________________

c. Number who died from suffocation? ____________________

d. What special factors are important regarding occupants (e.g., number thrown clear of the wreckage, rescue difficulties due to location of occupants, type of injuries, etc.)? ____________________

3. Describe Evacuation, Number of Rescue Personnel, Exits Used, Break-in Areas Used ____________________

____

____

4. Time Required to Accomplish Rescue and Removal of the Occupants ____________

____

____

5. Time Required to Control the Fire, ______________ minutes

6. Time Required to Extinguish the Fire, ______________ minutes

PART II

INSTRUCTIONS FOR COMPLETING THE NFPA DISASTER RESPONSE REPORT

PURPOSE

The purpose of Part II is to provide the information associated with an accident that can be used to update and refine disaster plans for other airports and communities involved in aviation operations. It also is used to provide data for the revision of NFPA 424M, *Manual for Airport/Community Emergency Planning*. Both the positive and negative consequences of the operation should be emphasized with the objective of improving safety to life in future accidents.

1. Data Collection

The information needed to complete this report can be obtained from the FAA, airline owner, or aircraft owner or their representatives and from representatives of the responding services.

2. Disaster Plan

A copy of the plan should be obtained. This provides the investigator with access to the telephone contacts necessary for obtaining details on the effectiveness of the response and a critique of the most recent exercise.

3. How Was the Alarm Received?

4. Response Times

Response times have a direct bearing on the entire rescue operation. They usually are reported to the Chair of the NTSB Human Factors Group during interviews with the responding agencies. Response times often are recorded on tapes maintained by the airport tower, fire departments, and emergency services. Where recorded times are not available, more than one source should be used for verification.

5. Responding Agencies

5.1 Mutual Aid Fire Services

The number of vehicles used for response and their function during the rescue operation are vital pieces of information that can affect future operations. Vehicle type should be recorded and identified as pumper, ladder, hose layer, etc. The arrival time of each vehicle and its effectiveness to the operation also should be recorded. Were the vehicles used to fight the fire or to replenish the ARFF vehicles? Were they used to maintain airport protection while the ARFF vehicles were fighting the fire? Were personnel used to extricate the victims? Only mutual aid off-airport vehicles should be included. DO NOT include airport ARFF crash trucks.

5.2 Helicopters

Include any helicopters that participated in the location or evacuation of survivors. Also include helicopters for news reporting that did not participate in the evacuation but aided traffic control.

5.3 Civil Defense

Include the vehicles responding and their part in the operation. Did they provide radio communications with other responders? What was their relationship to the command post?

5.4 Military

Include any military assistance provided at the scene, such as hazardous material control, helicopter response, etc. Provide the names of those units that assisted.

5.5 Police

Include local police responsible for maintaining ready access for emergency vehicles and crowd control.

5.6 Sheriff/State Patrol

Include any local security services that were involved. Was their participation effective, or did they interfere with the operation?

5.7 Airline/Airport Personnel

The first responders to an accident often are airport personnel who are working at the time of the accident. They provide help in any way they are able, from extrication of victims to personal care of the survivors. Include the number of responders, their affiliation, and the function they performed during the accident response.

5.8 Ambulance Services

It is often difficult to verify the identity of the first ambulance service to arrive at the scene, the number of survivors that service transported, and the medical facility to which survivors were taken. This section should include the names of the responding ambulance services, their approximate response times, and the number of patients whom they transported. Information on whether or not the ambulances were used also should be recorded.

5.9 Other Responders

Other responders should include the Red Cross, clergy, coroner, postal authorities, customs and immigration officials, and any additional participants not previously identified.

6. Rescue Operation

6.1 Mobile Command Post

Identify the operator of the command post and describe the type of vehicle. Was the vehicle self-propelled? Was it equipped with full emergency communication equipment? Is the vehicle owned by the airport authority, fire department, civil defense, or police? Approximately how long after the accident was the command post ready to assume control of the operation?

6.2 There usually is a change of on-scene commander during the course of operation. The first fire chief to arrive at the scene usually assumes command until replaced by the command post. Both persons should be identified.

6.3 Describe the type of command post (e.g., van, converted bus, trailer). How was it equipped (e.g., radio, VCR, mobile telephones)?

6.4 Was the command post easily recognizable while all responding vehicles were on the scene? How was it recognized?

6.5 Describe any problems encountered with communication procedures. These should include frequency congestion, incorrect frequencies, etc.

6.6 If an emergency operations center was used, describe its location and the effectiveness of its operation.

7. Triage

7.1 The triage operation may be permitted to be initiated by the airport EMTs, fire fighters, or the first responding medical unit.

7.2 The full triage operation usually is conducted by the medical authority identified in the disaster plan and usually is the medical facility located nearest the accident scene.

7.3 The location of the triage operation is of major importance. Its location relative to the accident, wind direction, and ambulance routing should be noted. How was the triage site marked?

7.4 Were emergency medical supplies available at the site? Where were they located, and how were they transported to the scene?

7.5 What were the terrain conditions at the site (e.g., swamp, trees, hills, level ground, etc.)? Did they affect efforts to set up the triage operation or the movement of the ambulances?

7.6 Were the ambulance movements controlled or did blockages result?

7.7 Note the approximate arrival times of doctors, nurses, and EMTs in relation to the time of the accident.

7.8 Note any reported obstacle to the triage operation, such as hypothermia, heat, and rain. Note the weather conditions at the time of the accident, such as temperature, precipitation, and visibility.

7.9 How were the victims tagged?

8. Medical Services

8.1 Identify the hospitals used during the emergency, the types of hospitals, such as eye, burn, trauma, etc., their distance from the accident site, and the number of casualties taken to each.

8.2 Were those who were injured but ambulatory taken to hospitals or first aid stations? Who cared for them before their release?

8.3 What provisions were made for the uninjured? Were they transported from the site? Where where they held? Were they separated from the news media? Were they provided with food and drink?

8.4 What provisions were made for the fatalities? Were there enough body bags? Where was the morgue set up? Was it set up using refrigerated trucks or other means?

8.5 Self-explanatory.

9. Police Security

9.1 At major airports, airport police are responsible for any airport emergency. They might, however, be a part of the city or county police. In the case of off-airport accidents, the security of the scene is under the control of the local authority.

9.2 The increase in airport security has resulted in several cases where the response of the emergency services was delayed by locked gates or restricted areas. Such interference with emergency response should be documented fully.

9.3 Were the emergency services delayed by highway traffic conditions?

9.4 Was the news media access controlled, or did they reach the site without authorization?

9.5 How was the general public restrained from access to the accident site?

9.6 For accidents that occurred on the airport premises, was an escort provided for mutual aid responders? Who provided the escort?

9.7 How long after the accident was the crash site secured? How was it secured (e.g., ropes, barriers, police protection)?

9.8 How were the mutual aid responders informed of the stage areas? Were they effective?

10. General

10.1 Which types of shoring materials, such as railway ties, were available to aid in extraction of the victims? Was heavy machinery, such as cranes or bulldozers, necessary for the operation?

10.2 If there were any problems with hazardous materials at the accident site, record the type of material and how it was handled.

10.3 Were all responders easily identified? How (e.g., baseball hats, armbands, vests, uniforms)?

11. Water Accidents

11.1 Many recent accidents have occurred in the water adjacent to the airport property.

Identify all responding water rescue agencies, such as Coast Guard or police, and also record any water rescue equipment maintained by the airport authorities.

11.2 Some aircraft carry only floatable seat cushions. Others carry only life vests, while still others carry full overwater equipment, including rafts and life vests.

11.3 Was any additional flotation equipment transported to the scene? How was it used?

11.4 Record the water and weather conditions at the time. Both air and water temperatures should be recorded. Was visibility restricted by fog or darkness?

11.5 Describe any problems locating aircraft.

11.6 Underwater search and recovery

11.7 Any resuscitation of victims of hypothermia due to near-drowning in cold water?

PART II NATIONAL FIRE PROTECTION ASSOCIATION DISASTER RESPONSE REPORT

Aircraft no. ____________________ Flight no. ________________

Type of aircraft ____

Aircraft operator ____

Date of accident ____

1. Data Collection

Number of occupants:

Cockpit crew ____

Cabin crew ____

Passengers ____

Other persons involved and location

____

____

Number occupants escaped unaided, uninjured ____

Number occupants escaped unaided, ambulatory, injured ______________________________

Number rescued ____

Number of trauma-related fatalities________________ Fire-/smoke-related fatalities _______

Other fatalities ____

Time last survivor was evacuated ____

2. Disaster Plan

Date of last revision ____

Date of last inspection ____

Is plan current? ____

IF NOT, WHY? ____

Incorrect telephone numbers ____

Incorrect radio frequencies ____

Incorrect agencies, names, etc. ____

Date of last full-scale exercise ____

Date of last table top exercise ____

Did all responding agencies participate in the exercises? ______________________________
IF NOT, EXPLAIN ____
Dates of any mini exercises in last two years ____
Review of mutual aid agreements ____

3. How Was Alarm Received? ____
____
____

4. Response Times	Local
Time of accident	________
Initial notification of ARFF	________
Arrival of ARFF	________
Disaster plan activation	________
Triage initiated	________
First casualty transported to hospital	________
Arrival of mobil command post	________
Arrival of first medical services	________
Arrival of transportation for uninjured	________
Arrival of first ambulances	________
Arrival of police/security services	________
Arrival of mutual aid fire services	________
First casualty transported to hospital	________
First and last vehicle arrival at hospital	________
Last casualty transported to hospital	________
Response terminated	________

5. Responding Agencies

5.1 Mutual Aid Fire Services

Mutual Aid Fire Services

			Amount of Agent Carried Check One Gallons ________ Liters ________		
Agency	Vehicle Type	Time of Arrival	Water	Foam	Other

Other ____

Use extra sheet if number exceeds ten.

How were these vehicles utilized? ____

____

____

Primary fire fighting ______________ Tankers ____________ Rescue __________

Standby for continuing flight operations ____

Other ____

5.2 Helicopters

Were helicopters used during the emergency? ________________________________

To locate accident site? ____

To control traffic? ____

To transport casualties to hospital? ________________________________

Record the owner and/or operator of each helicopter

(a) Arrival time ____

____

(b) Arrival time ____

____

(c) Arrival time ______________________________

____

(d) Arrival time ______________________________

____

5.3 Civil Defense ______________________________

5.4 Military ______________________________

5.5 Police ______________________________

5.6 Sheriff/State Patrol ______________________________

5.7 Airline/Airport Personnel ______________________________

5.8 Ambulance Services ______________________________

Ambulance Services

Owner/Operator	Number Medical Personnel Provided	Patient Capacity	Arrival Time at Scene	Used/Not Used

Medical Personnel

Doctors ______________________________

Nurses ______________________________

EMTs ____________ ALS ____________ BLS ____________

5.9 Other Responders ______________________________

6. Rescue Operation

6.1 Mobile command post ______________________________

How long after the accident was the command post ready to assume control of the operation? ______________________________

6.2 Who was the on-scene commander? ______________________

Was the incident command system (ICS) used? ______________________

Problems with the ICS? ______________________

6.3 Was the mobile command post (MCP) power-driven or trailer? ____________

6.4 Was the MCP easily recognizable? ______________________

How? Lights ____________ Balloon __________ Other _______

6.5 Was communication with responding agencies adequate? ______________

Radio _____ Telephone _____ Land/cellular _____ Fax _____
Other _____

Problems with communication ______________________

____

6.6 Was an emergency operations center available? ______________________

7. Triage

7.1 Who initiated triage operations? ______________________

7.2 Who conducted the triage operation? ______________________

7.3 Where was triage operation set up in relation to the accident?

Describe location showing ambulance arrival and departure routes __________

____

____

7.4 Were emergency medical supplies available at the site? ______________

7.5 Was terrain or weather a problem? If so, describe. ______________

____

7.6 Were ambulance arrivals/departures controlled in an orderly manner? ________

7.7 Arrival time of first Doctors __________ EMTs _____ Nurses _____

7.8 What were the weather conditions at the accident site?

Temperature _____ Wind Direction _____ Wind Velocity __________

Precipitation ____________ Visibility __________

7.9 How were the victims tagged? ______________________

8. Medical Services ______________________________

8.1 Hospital distribution

Name of Hospital	Type	Distance from Incident	Arrival Time	Number of Casualties

8.2 How were the injured but ambulatory treated?

First aid at site ______________________ Transported to hospital ________________

8.3 What provisions were made for the uninjured/ambulatory?

Transported to the terminal by bus ________________ Other __________________

Provided with telephones ______________ Food ______ Drink __________

8.4 What provisions were made for the fatalities?

Body bags available ______________ Temporary morgue ________________

Other ____

8.5 Were the services of the following available?

Coroner ________________ Clergy __________ Post office ____________

Customs____________________ Red Cross ________________

9. Police/Security

9.1 Who provided the police services?

Airport ______________ County __________ State ________ City ____________

9.2 Describe problems encountered regarding airfield/site access in detail ____________

____

9.3 Was highway traffic control adequate for the responding agencies? ______________

____

Were there any street closure plans implemented? ______________________________

____

9.4 Was the news media access coordinated?________________ How? ____________

9.5 Was crowd control maintained? __________________ How? __________________

9.6 Who provided vehicle escort for accidents on the airport premises?

Airport police ____________ Airport authority ____________ Other ____________

9.7 How long after the accident was the crash site secured? ________________________

How? ____

9.8 Were off-airport emergency services informed of staging areas and rendezvous points? ____

10. General

10.1 Which types of heavy equipment and shoring materials were available for extrication purposes? ____

10.2 If a hazardous materials team was needed, describe problem involved ____________

10.3 Were all responders easily identified? ____________________________________

How? Vests ______ Hats __________ Armbands ________ Uniforms __________

11. Water Accidents

11.1 What was the method of response to the accident?

Boats________ Amphibious vehicles ______ ARFF vehicles ______ Swamp buggies ______

Time and distance to reach the accident scene ________________________________

Water Rescue Equipment

Agencies	Type	Size	Response Time	Passenger Capacity

11.2 Were survivors equipped with aircraft floatation equipment?

Life vests ________ Slides __________ Rafts ________ Seat cushions __________

11.3 What flotation equipment was transported to the scene?

Rafts ________________ Platforms __________ Life vests____________

11.4 Indicate weather and water conditions

Water: Smooth ______ Choppy________ Rough________ Temperature__________

Air temperature __________________ °F __________ °C

Other factors affecting rescue operations ____________________________________

11.5 Describe any problems locating aircraft ____________________________________

11.6 Underwater search and recovery ____

11.7 Any resuscitation of victims of hypothermia due to near-drowning in cold water? ____

COMMENTS ____

____

____

Name ____

Representing ____

Telephone contact ____

Date ____

Chapter 3 Referenced Publications

3-1

The following documents or portions thereof are referenced within this guide and should be considered part of the recommendations of this document. The edition indicated for each reference is the current edition as of the date of the NFPA issuance of this document.

3-1.1 NFPA Publications.

National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.

NFPA 407, *Standard for Aircraft Fuel Servicing*, 1990 edition.

NFPA 424M, *Manual for Airport/Community Emergency Planning*, 1991 edition.

NFPA 1001, *Standard for Fire Fighter Professional Qualifications*, 1992 edition.

NFPA 1003, *Standard for Airport Fire Fighter Professional Qualifications*, 1994 edition.

NFPA 1500, *Standard on Fire Department Occupational Safety and Health Program*, 1992 edition.

NFPA 1971, *Standard on Protective Clothing for Structural Fire Fighting*, 1991 edition.

NFPA 1976, *Standard on Protective Clothing for Proximity Fire Fighting*, 1992 edition.

Appendix A Explanatory Material

This appendix is not a part of the recommendations of this NFPA document but is included for informational purposes only.

A-1-2 State and International Documentation.

The purpose of preparing these reports is NOT to investigate the cause of this accident, but is to provide data that can be used to prevent injury and loss of life in future accidents.

Appendix B

This appendix is not a part of the recommendations of this NFPA document but is included for informational purposes only.

The following information may be of use to persons investigating the fire.

B-1 Fire.

B-2

In most cases where there is evidence that a specific temperature has been attained, a time-temperature relationship exists, so that it is not always possible to determine a precise temperature. A temperature of 1,500°F (816°C) sustained for a few minutes can create the effect of fire that has burned at a lower temperature for a longer duration. There are sometimes specific points at which a temperature change occurs, in which case temperature ranges can be defined more closely. Laboratory analysis sometimes is needed, but investigators usually can trace or plot a fire pattern to a source point by studying the relative temperatures and the position of the burned or overheated area.

B-3

Fire resistance is not a property of a particular material but is a characteristic of a particular system comprising material, oxidant, ignition source, and environmental conditions. For example, ordinary steel at room air temperature is not ignitible with an ordinary match — unless the steel is in the form of loosely packed steel wool. Such a distinction in the form of a material often is overlooked when interpreting fire data.

B-4

Most aluminum sheet and forging ingots used for aircraft components are from the 2000 and 7000 series. The 2000 series is an alloy that uses copper as the major alloy material (approximately 4 to 5 percent); the 7000 series uses zinc as its major alloy (approximately 5 to 6 percent). All alloys are approximately 95 percent aluminum, and most include very small percentages (in terms of chemical content) of other metals, such as titanium, silicon, manganese, magnesium, etc. The melting point of the sheet used generally is around 1,180°F (639°C), but a few alloys can melt at temperatures as low as 980°F to 1,000°F (527°C to 538°C). Very few forgings or castings melt at temperatures as low as 950°F (510°C). The letters used with aluminum series numbers designate temper and strain hardening. For example, 7075-T-6 contains 5.1 to 6.1 percent zinc plus small amounts of eight other elements, is solution heat-treated, and is artificially aged.

B-5

Certain types of heat treatment and strain hardening often change the basic characteristics of metal (e.g., from ductile to brittle), and these changes can cause alterations in appearance. Plating also tends to change characteristics.

B-6

When aluminum alloys are heated to the melting range, they wrinkle and pull apart, leaving bright cracks and fissures. If heated sufficiently to form droplets, they appear as little wrinkled bags. By comparison, iron alloys tend to burn when heated to the red range, forming oxides at the edges and in thin sections.

B-7

Fire damage to metal is manifested mainly in loss of strength. For example, 7075-T-6 alloy loses 10 percent of its strength when heated for 30 minutes at 400°F (204°C); 10 minutes at 450°F (232°C); 3 minutes at 550°F (288°C); or 2 minutes at 600°F (316°C). Hardness tests can be used to determine the amount of temperature exposure, but an estimate of the length of exposure is necessary to determine the maximum temperature.

B-8

Titanium changes color from tan to light blue to dark blue to grey as the temperature increases. It reacts strongly to gases when heated, and a scale begins to form at approximately 1,100°F (593°C). This scale increases in thickness with time and turns bluish in color. At approximately 1,200°F to 1,500°F (649°C to 816°C), a grey or yellowish shade appears. At approximately 1,300°F (704°C), an appreciable oxide scale forms, which flakes off. At approximately 1,620°F (882°C), titanium undergoes an allotropic transformation (from alpha type to beta type), and the oxidation rate increases significantly. Titanium fires in turbine engines have been a cause of concern for some time; they start quickly, are difficult to detect, and are nearly impossible to extinguish. They can occur in the total absence of hydrocarbon or other fuel sources, a fact that, in itself, is evidence of a titanium fire. The mechanism of titanium (Ti) fires is complex. The scenario for a fire caused by titanium rotor blades might involve the following sequence:

(a) A Ti rotor blade can rub against the engine case and, because of the low thermal conductivity of Ti, the temperature of the blade can increase rapidly;

(b) Ti melts at about 3,100°F (1704°C);

NOTE: Steel melts at about 2,700°F (1482°C).

(c) Molten Ti absorbs O_2 to form TiO_2, which boils, burns, and stabilizes at approximately 5,600°F (3093°C);

(d) The TiO_2 continues to form and burn as long as there is an air supply. Molten Ti at very high temperatures melts through steel engine cases rapidly. (For this reason, engine design should avoid routing fuel and oil lines in the lower sector of the engine.)

B-9

Stainless steel changes color from tan to light blue to bright blue to black starting at 800°F to 900°F (427°C to 482°C). When examining stainless steel after heating, the investigator should check both sides; the lighter blue side is the side that was positioned opposite the heat source, and the heated area will be smaller in circumference.

B-10

Zinc chromate paint primers start to tan at 450°F (232°C) and turn brown at 500°F (260°C), dark brown at 600°F (316°C), and black at 700°F (371°C). Cadmium plating begins to discolor at 500°F (260°C). Glass cloth fuses at 1,200°F (649°C). Silicone rubber blisters at 700°F (371°C). Neoprene rubber blisters at 500°F (260°C). Wire insulation is a good guide for determining lower temperature ranges if the material is known [e.g., nylon spaghetti melts at 250°F to 350°F (121°C to 177°C).]

B-11

Aircraft paints soften at 400°F (204°C), discolor at 600°F (316°C), blister at 800°F to 850°F (427°C to 454°C), and burn off completely at 900°F to 950°F (482°C to 510°C). Cutting through the paint with a sharp knife discloses the depth of overheating. Severe scorching blackens the surface without further darkening it. It is unusual to find metal beneath paint damaged if the paint is not burned through completely. It is possible to char primer beneath heat-resisting aluminum paint without apparent “surface” burning.

B-12 Temperature Limits of Selected Materials.

B-12.1

The investigator should note carefully those materials that ignited, those that melted, and those that were damaged by heat.

B-12.2

Tables B-12.2(a) and B-12.2(b) provide a list of materials and their autoignition temperatures and a list of materials and those temperature limits that damage or distort them. The materials selected usually are found in private or commercial transport aircraft.

Table B-12.2(a) Autoignition Temperature of Selected Materials

	°F	°C
Canvas	204	96
Denatured alcohol	750	399
Hydraulic hose (Buna-N-Rubber)	950	510
Leather	850	454
Nylon-covered wire	1000	538
Glass matts	950	510
Lubricating oil (MIL-1-7808)	790	421
Plywood	900	482
Rubber-covered wire	900	482

Vinyl-covered wire	900	482
Rubber-asbestos material	900	482
Styrene	914	490
Teflon	1050	566

Table B-12.2(b) Temperature Limits for Selected Materials

	°F	°C
Glaze or electrical porcelain	2250	1232
Enamel flakes	1200-1400	649-760
Glass softens	1400-1600	760-871
Paraffin wax melts	129	54
Zinc melts	786	419
Silver solders melt	1165-1450	629-789
Silicone rubber (considerable softening at sustained service)	425	218
Cellulose (filled melamine, heat distortion)	400	204
Nylon (polyamide), heat distortion	300-360	149-182
Melamine-formaldehyde (filled), heat distortion	266-400	130-204
Paper phenolic, delamination and distortion	250	121
Styrene elastomer, distortion at sustained service	220	104
Polystyrene, distortion	210	99
Methyl methacrylate, heat distortion	210	99
Plastic vinyl chloride, heat distortion	185	85

B-12.3

Table B-12.3 provides melting points for metals and alloys used in current aircraft. It is essential that the investigator be familiar with various aircraft metals and alloys and well-informed regarding their purpose and their location in the aircraft.

Table B-12.3 Melting Points of Some Aircraft Metals and Alloys

	°F	°C
Aluminum alloys	1220-1250	660-677
Brass bearings	1600-2000	871-1093
Cadmium	609	321
Chromium	3430	1889
Copper	1981-2000	1083-1093
Iron	2802	1539
Lead	621	327
Magnesium alloys	1202-1250	650-677
Manganese	2273	1243
Mercury	39.9	39.9
Molybdenum	4760	2627
Nickel	2651	1455
Selenium	428	220
Silicon	2605	1429
Silver	1760	960
Stainless steel	2700	1482
Tin	449	232
Titanium	3100	1704
Tungsten	6170	3410
Vanadium	3150	1732

B-13

If electrical wire breaks when no current is flowing, the break will be clean and will display a typical cup-and-cone fracture with necking down. If current is flowing, it arcs when the wire breaks, causing little balls of oxidized metal to form on the tips of the wire strands. A fire external to the wiring bundle burns the outside first, and the conductor inside will remain clean and bright, except where the insulation has burned through. Wires burned due to excess current burn from the inside out, and the conductor will be dark and oxidized, perhaps without damage to the outer cover. The tin coating on copper wire will diffuse into the copper at temperatures above its melting point of 449°F (232°C) and become rough or even disappear. On-scene examination should be only for general observation and possible conclusions. Detailed laboratory examination should be performed to confirm the mechanism of the wire faults and failures. Additionally, chemical analysis of wire breaks can reveal the presence of combustibles during the failure.

B-14

Examination of any surviving light bulbs helps in determining if electrical power was on in a particular system at the time of impact. The filaments of small bulbs will indicate if the bulb was illuminated at impact, when the bulb was shock-loaded. If the filament was hot at impact, it will stretch and distort substantially; if the filament was cold at impact, it will break but will not distort or stretch from its original shape and pattern. If the glass shattered and the filament was exposed, it will provide the information but will oxidize and discolor quickly. This entire procedure is valuable in determining the system operational status at impact, provided failure lights and warning light bulbs survive any subsequent fire in this area. (*See ICAO DOC 6920-AN/855/4, Manual of Aircraft Accident Investigation, Part III, 7.3, "Electrical Systems," for further information on fire origin*.)

B-15

All hydrocarbon fuels used in aircraft leave a similar soot residue (except when instantaneous combustion or explosion occurs, in which case no sooting is left) so that tests might not be successful in identifying or differentiating between these and various other hydrocarbon liquids that are found about aircraft. Cleaning fluids, oils, etc., can leave similar residues. Soot does not deposit or adhere to surfaces that are above 700°F (371°C).

B-16 Flammability Characteristics of Aviation Fuels.

B-16.1

There are three basic types of aviation fuels: aviation gasoline (AVGAS), the kerosene grades (JET A, JET A-1, JP-5, JP-6), and the blends of gasoline and kerosene (JET B, JP-4). The flammability characteristics of these fuels are provided in Table B-16.4, but a brief comparison is included to focus attention on their differences.

B-16.2

In order to burn, all petroleum fuels need to be vaporized and mixed with air in specified proportions. AVGAS has a strong tendency to vaporize and, as a result, the air over the surface of the liquid always is mixed with a considerable quantity of vapor. In a closed tank, so much fuel vapor is given off by AVGAS that the fuel-air mixture can be too rich to burn. When any fuel is in contact with air, it continues to evaporate until the air is saturated.

B-16.3

Kerosene grade fuel ordinarily has a low tendency to vaporize, and, in a closed tank, the fuel vapor and air mixture can be too lean to burn. However, kerosene grade fuels can be ignited by heating them above their flash point. It also is possible to ignite such fuels without heating the bulk of the fuel to flash point. This can be achieved by wicking the fuel on an absorbent material that can be heated locally (hot spot) until the fuel ignites. The hot spot on the wick furnishes sufficient vapor to sustain the flame. Such conditions can occur accidentally during crash and post-crash conditions.

B-16.4

Fuels that contain a blend of AVGAS and kerosene retain most of the worst fire characteristics of both fuels. (*See Table B-16.4*.) The vapor mixture in a closed tank normally is neither too rich nor too lean. Flammability limits include a wide temperature range, autoignition temperature is low, and flame spread is almost as fast as when using AVGAS.

Table B-16.4 Flammability Characteristics of Aviation Fuels†

	Gasoline	Kerosene Grades	Blends of Gaso
Characteristics	**AVGAS**	**JET A, JP-5, JP-6 / JET A-1**	**JET B**
Freeze Point	–76°F	–40°F / –58°F	–
Vapor Pressure (ASTM D323)	5.5 to 7.0 lb/sq in.	0.1 lb/sq in.	2.0 to 3
Flash Point (by closed-cup method at sea level)	–50°F	+95°F to +145°F	–10°F
Flash Point (by air saturation method)	–75°F to –85°F	None	–
Flammability Limits			
Lower Limit	1.4%	0.6%	0
Upper Limit	7.6%	4.9%	5
Temp. Range for Flammable Mixtures	–40°F to +30°F	+95°F to +165°F	–10°F
Autoignition Temperature	–825°F to +960°F	+440°F to +475°F	+470°F
Boiling Points			
Initial	110°F	325°F	1
End	325°F	450°F	4
Pool Rate of Flame Spread*	700 ft-800 ft per min	100 ft per min or less	700 ft-80

For SI Units: 1°C = $^5/_9$ (°F - 32); 1 psi = 6.895 kPa; 1 ft = 0.3048 m.
† For further information, see NFPA 407, *Standard for Aircraft Fuel Servicing.*
* In mist form, rate of flame spread in all fuels is very rapid.

B-17

When heated, some hydraulic fluids vaporize into a white mist that is acrid and causes choking. When burned, the residue is first dark-colored and viscous; then it changes to a dark-charred material, and a white, fluffy deposit appears after prolonged heat. When burned, hydraulic fluids produce a yellowish flame with white smoke. If Skydrol® (a trade name hydraulic fluid commonly used in current aircraft) is heated and a piece of aluminum is placed in it, an acetylene-type odor is evident. Skydrol 500 has a flash point of approximately 440°F (227°C), and autoignition occurs at approximately 925°F (496°C). In mist form, it can ignite at room temperature.

B-18

The aging of fluids (such as oil and hydraulic fluid) is caused by an increase in their acidity over time. This acidity tends to lower the flash point, but the problem is considered negligible, since a complete fluid change by volume is performed on the average aircraft at least four times per year. The flash points provided in Table B-16.4 are based on standard sea level pressure; lower pressures reduce the flash point and increase volatility. Fuels cannot burn unless in the vapor state, and the mixture ratio determines whether a fuel can burn. Skydrol and other ester-based fluids also possess these same properties.

Appendix C Referenced Publications

C-1

The following documents or portions thereof are referenced within this guide for informational purposes only and thus are not considered part of the recommendations of this document. The edition indicated for each reference is the current edition as of the date of the NFPA issuance of this document.

C-1.1 NFPA Publication.

National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.

NFPA 402M, *Manual for Aircraft Rescue and Fire Fighting Operations*, 1991 edition.

C-1.2 ICAO Publication.

International Civil Aviation Organization, 1000 Sherbrooke Street, W, Montreal, PW, Canada 3A 2R2.

DOC 6920-AN/855/4-1970, *Manual of Aircraft Accident Investigation*.

NFPA 423

1994 Edition

Standard for Construction and Protection of Aircraft Engine

Test Facilities

1994 Edition

This edition of NFPA 423, *Standard for Construction and Protection of Aircraft Engine Test Facilities*, was prepared by the Technical Committee on Airport Facilities and acted on by the

National Fire Protection Association, Inc., at its Annual Meeting held May 16–18, 1994, in San Francisco, CA. It was issued by the Standards Council on July 14, 1994, with an effective date of August 5, 1994, and supersedes all previous editions.

The 1994 edition of this document has been approved by the American National Standards Institute.

Changes other than editorial are indicated by a vertical rule in the margin of the pages on which they appear. These lines are included as an aid to the user in identifying changes from the previous edition.

Origin and Development of NFPA 423

The Sectional Committee started work on this standard in 1972. It was first submitted to the association at the 1975 Fall Meeting but was returned to committee for coordination with the NFPA Committee on Fire Tests. The 1977 edition contains the results of that coordination effort. The standard was reconfirmed in 1983. The 1989 edition was a complete revision of the 1983 edition. The 1994 edition is a partial revision of the standard.

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Arnold M. Sloane, The Port Authority of NY & NJ, NY
Rep. Airport Operators Council Int'l, Inc

Doug Toupalik, Ansul Fire Protection/Wormald U.S., Inc., WI
Rep. Fire Equipment Manufacturers' Assn., Inc.

Fred K. Walker, U.S. Air Force, FL

Alternates

Michael E. Aaron, Rolf Jensen & Assoc., Inc., IL
(Alt. to D. C. Kennedy)

Thomas G. Burk, Federal Express Corp., TN
(Alt. to D. R. Chase, Jr.)

James Devonshire, Chubb Nat'l Foam, PA
(Alt. to F. M. Linde)

Robert D. Grausam, Kemper Nat'l Insurance Cos., NY
(Alt. to J. D. Dick)

Willard R. Ham, M&M Protection Consultants, CA
(Alt. to J. R. Ballinger)

Frank M. E. Hughes, British Airways, England
(Alt. to J. J. O'Sullivan)

Michael L. Jones, Industrial Risk Insurers, CA
(Alt. to J. M. Ingalls)

Keith C. Kremkow, Johnson & Higgins, IL
(Alt. to Johnson & Higgins Rep.)

John E. Loehle, Air Nat'l Guard Readiness Center, MD
(Alt. to F. K. Walker)

Robert C. Merritt, Factory Mutual Research Corp., MA
(Alt. to L. M. Krasner)

Mark Oliszewicz, Schirmer Engineering Corp., IL
(Alt. to G. R. Schultz)

V. G. Pyrpyris, The Port Authority of NY & NJ, NY
(Alt. to A. M. Sloane)

Nonvoting

J. Walter Coon, Black and Veatch, MO
(Member Emeritus)

Jerome Lederer, Laguna Hills, CA
(Member Emeritus)

Mark T. Conroy, NFPA Staff Liaison

This list represents the membership at the time the Committee was balloted on the text of this edition. Since that time, changes in the membership may have occurred.

NOTE: Membership on a Committee shall not in and of itself constitute an endorsement of the Association or any document developed by the Committee on which the member serves.

Committee Scope: This Committee shall have primary responsibility for documents on fire safety for the construction and protection at airport facilities involving construction engineering but excluding airport fixed fueling systems.

NFPA 423

Standard for

Construction and Protection of

Aircraft Engine Test Facilities

1994 Edition

NOTICE: An asterisk (*) following the number or letter designating a paragraph indicates explanatory material on that paragraph in Appendix A.
Information on referenced publications can be found in Chapter 7 and Appendix B.

Chapter 1 Administration

1-1 Scope.

1-1.1

This standard establishes the minimum fire safety practices regarding location, construction, services, utilities, fire protection, operation, and maintenance of aircraft engine test facilities. These facilities include test cells and test stands.

1-1.2

This standard does not apply to engines and engine accessories, nor to engine test facilities where other than hydrocarbon fuels are used.

1-2 Purpose.

The purpose of this standard is to provide a reasonable degree of protection, for life and property from fire, for aircraft engine test facilities, based upon sound engineering principles, test data, and field experience.

1-3 Definitions.

Approved.* Acceptable to the authority having jurisdiction.

Authority Having Jurisdiction.* The organization, office, or individual responsible for approving equipment, an installation, or a procedure.

Control Room. A room with instrumentation and devices to control, measure, record, or observe test cell and engine operation and performance.

Detection System. A system consisting of detectors, controls, control panels, automatic and manual actuating mechanisms, all wiring, and all associated equipment.

Engine Rundown Time. The time required for the engine under test to have reduced its rotational speed to 10 percent of that at full power (100 percent).

Engine Test Cell. The space in which the test engine is installed on a thrust stand during a test. This space is totally enclosed by permanent building components except where the enclosure is breached by air ducts, services, access ports, or doors.

Engine Test Facility. An integrated system of building(s), structure(s), space, and services used to test aircraft engines contained within a test cell or on a test stand.

Engine Test Stand. An integrated system for testing an aircraft engine, as in a test cell, except that the engine test space is not totally enclosed within a permanent building.

Listed.* Equipment or materials included in a list published by an organization acceptable to the authority having jurisdiction and concerned with product evaluation that maintains periodic inspection of production of listed equipment or materials and whose listing states either that the equipment or material meets appropriate standards or has been tested and found suitable for use in a specified manner.

Shall. Indicates a mandatory requirement.

Should. Indicates a recommendation or that which is advised but not required.

Support Room. An enclosure or area, excluding the test cell or control room, that is an integral part of engine testing, including fuel handling rooms, hydraulic rooms, preparation areas, mechanical/electrical rooms, etc.

Test Cell. See Engine Test Cell.

Chapter 2 Construction and Internal Subdivisions

2-1 Construction of Aircraft Engine Test Facilities.

2-1.1

Test cell walls, ceilings, and floor assemblies shall be at least Type II (222) construction as defined in NFPA 220, *Standard on Types of Building Construction*.

2-1.2

Materials of construction such as thermal or acoustic insulation used within the test cell shall be noncombustible as defined in Chapter 2 of NFPA 220, *Standard on Types of Building Construction*.

2-1.3

Engine test facilities shall be constructed without basements or below grade areas other than those recesses in the floor necessary to accommodate sump pumps, drainage facilities, or lifting platforms.

2-1.3.1 In existing facilities, all basement areas, tunnels, or other below grade spaces shall be eliminated; or the fuel handling system shall be segregated, drainage shall be provided, and the basement area cut off so as to eliminate the possibility of flammable vapors collecting in the basement area or a spill of flammable or combustible liquids discharging into a basement area.

2-1.4*

An explosion hazard analysis of the engine test cell shall be performed to determine if an explosion hazard exists capable of compromising the integrity of the structure. If the analysis indicates such a hazard exists, one of the following shall be incorporated:

(a) Explosion venting;

(b) Explosion suppression system;

(c) Explosion limiting construction.

2-2* Internal Subdivisions of Aircraft Engine Test Facilities.

Engine test cells, fuel handling areas, and hydraulic rooms shall be separated from adjacent areas by construction having a minimum fire rating of 2 hours.

Chapter 3 Service and Utilities

3-1 General Safeguards.

3-1.1*

All objects, such as supports, nuts, and bolts, located where they might be ingested into an aircraft turbine engine shall be positively secured by safety wires, tack welding, suitable adhesive, or approved aircraft-type locking devices; or an inlet screen of proper design shall be used to protect an engine from foreign object damage.

3-1.2

All materials likely to become exposed to fuels, oils, or hydraulic fluids shall be resistant to deterioration from the fuels being used.

3-2 Drainage Systems.

3-2.1*

Drainage systems shall be provided for engine test cells and support rooms containing flammable or combustible liquid handling systems to reduce the fire and explosion hazards.

3-2.2

Floors subject to possible spillage of flammable or combustible liquids shall be pitched a minimum of one percent toward the drain(s). Drain(s) shall be located to minimize fuel spread and exposure to equipment.

3-2.3

Curbs, ramps, or drain trenches shall be installed to prevent the flow of flammable or combustible liquids into adjacent rooms or buildings.

3-2.4*

Drainage systems shall be designed and installed to provide sufficient capacity to prevent buildup of flammable or combustible liquids and water over the drain inlet under maximum possible water discharge rate.

3-2.5*

Drain traps shall have a trap seal water head. In test cells, the seal water head shall be greater than the expected difference between the test cell operating pressure and atmospheric pressure.

3-2.6

Drain piping and joints shall be resistant to deterioration from fuels, engine oil, and aircraft hydraulic system fluids.

3-2.7

Common or separate oil separator(s) shall be provided in drains from the engine area, the exhaust plenum area, and support rooms. Separator systems shall discharge flammable or combustible liquid products to an approved, safely located tank, cistern, sump, or pond away from or cut off from the engine test facility. In aircraft engine test facilities protected by a fire protection system utilizing water, a bypass shall be provided around the separator to allow for emergency direct disposal of water and flammable liquids to an approved location.

3-2.8

Maintenance checks and flushing shall be conducted on all drains and oil separators at least annually to assure that they are clear of obstructions.

3-3 Electrical.

3-3.1

Any pit, depression, or other below floor level locations of engine test cells, fuel handling areas, and hydraulic rooms shall be classified as a Class I, Division 1 Hazardous Location as defined in Article 500, Chapter 5, of NFPA 70, *National Electrical Code*®. This classification shall extend up to floor level.

3-3.2

The engine test cell including intake and exhaust plenums, fuel handling areas, and hydraulic rooms shall be classified as a Class I, Division 2 Hazardous Location as defined in Article 500, Chapter 5, of NFPA 70, *National Electrical Code*. This classification shall extend up to a level 18 in. (0.46 m) above the floor.

3-3.3*

All wiring and equipment that is installed or operated within any of the hazardous locations specified in this section shall comply with applicable provisions of Article 501, Chapter 5, of NFPA 70, *National Electrical Code*.

3-3.4

When wiring is located in vaults, pits, or ducts below the test cell floor, drainage shall be provided.

3-3.5

All wiring in the exhaust plenum not within the hazardous location as specified in 3-3.2 of this section shall be installed in rigid conduit.

3-3.6

All other test facility wiring not within a hazardous location shall meet the requirements of Chapter 3 of NFPA 70, *National Electrical Code*.

3-3.7

All wiring not enclosed in raceways, such as harness wires connecting to the engine, shall be adequately supported, laced, or banded to minimize wear from air velocity and vibration.

3-3.8*

A means shall be provided at the control console to shut off all electric power other than emergency circuits to the test cell in the event that the engine disintegrates or fuel leaks develop during operation.

3-4 Heating and Cooling.

3-4.1*

Heating and cooling systems shall be arranged to

(a) Reduce exposure of their vital elements to fire, explosion, and damage by metal;

(b) Eliminate introduction of ignition sources by components of heating systems;

(c) Minimize passage of fire through ductwork; and

(d) Eliminate pockets in which flammable vapors can accumulate.

3-4.2*

Steam, hot water, or indirect warm-air heating systems shall be used for general room or building heating in areas where flammable or combustible liquids or flammable gases are handled. Where flammable or combustible liquids or heavier-than-air flammable gases are used, return openings in hot air systems shall be located a minimum of 10 ft (3 m) above the floor. A conveniently located remote control station shall be provided to shut down the warm-air heating system.

3-4.3*

Cooling systems utilizing flammable refrigerants shall not be installed nor used within the test cell.

3-4.4*

When direct-fired inlet air preheaters are essential to simulate hot inlet air conditions, fuel safety controls as specified in NFPA 86, *Standard for Ovens and Furnaces*, shall be provided. Interlocks shall be provided to prevent ignition of a direct-fired system until adequate airflow has been established within the test cell or the engine is running.

3-4.5

Direct-fired or indirect-fired heaters for heating test cell inlet air shall be designed in accordance with applicable sections of NFPA 31, *Standard for the Installation of Oil-Burning Equipment*; NFPA 54, *National Fuel Gas Code*; and NFPA 58, *Standard for the Storage and Handling of Liquefied Petroleum Gases*.

3-5 Ventilation.

3-5.1*

Continuous forced ventilation using fresh air at the rate of at least 2 cu ft per min per sq ft (0.01 cu m per sec per sq m) of floor area shall be provided in all support rooms handling flammable or combustible liquids.

3-5.2

Ventilation systems shall be arranged to draw heavier-than-air vapors or gases from near the floor level and discharge to a safe location. Where lighter-than-air gases are used, similar ventilation shall be provided but arranged to exhaust from ceiling level and with calculations based on the ceiling area. Ventilation for lighter-than-air gases shall be designed to prevent pocketing of such gases at ceiling level. Rotating elements of fans shall be of nonferrous or nonsparking materials, or the casing shall consist of or be lined with such material.

3-5.3

Where ventilation is provided, each cell or room handling flammable or combustible liquids or flammable gases shall have its own ventilation system in order to avoid interconnecting multiple hazards.

3-6 Fuel Systems and Lubricating Oil Systems.

3-6.1

Fuel systems and lubricating oil systems shall meet the requirements of NFPA 30, *Flammable and Combustible Liquids Code*. Plastic, aluminum, or cast iron shall not be permitted to be used aboveground for pipe, valve bodies, and fittings in test facilities.

3-6.2*

Fuel systems shall be equipped with manually operated control valves located at strategic points both outside and inside the engine test facility so that the main fuel supplies can be shut down quickly in the event of an emergency.

3-6.3*

Emergency safety shutoff valve(s) shall be installed in the fuel supply line(s) to each test cell and shall be located outside each test cell. These valves shall close on operation of a readily accessible and placarded emergency control device.

3-6.4

Fuel lines from main fuel headers shall enter fuel handling areas and run to test cells without passing through the control room. Relief valves arranged to discharge into collection tanks or fuel return lines, or other suitable devices, shall be installed in the piping system to protect the piping and equipment against overpressure due to thermal expansion of liquid in valved-off sections.

3-6.5

Glass fuel flow measuring devices shall not be used.

3-6.6

Flexible sections in the fuel and lubricating oil systems shall be suitable for the fluid and for the temperature and pressure to be expected.

3-6.7

Fuel and lubricant piping within the test cell shall be located as to minimize exposure from physical damage.

3-7 Compressed Air.

3-7.1

Compressed air piping systems shall conform to requirements of ANSI B31.1, *Code for Power Piping*.

3-7.2

Materials in compressed air piping systems shall be rated for the conditions of pressure and temperature expected. They shall be resistant to the fuels, oils, or hydraulic fluids to which they could be exposed.

3-7.3

Hose bands and joint couplings shall be of an approved type, and shall be safety wired.

3-8 Hydraulic Fluids.

3-8.1*

Hydraulic systems shall be designed in accordance with ANSI B31.1, *Code for Power Piping*. Piping and fittings shall be designed to withstand maximum surge pressures in the system. Piping shall be securely mounted to prevent failure due to vibration or mechanical damage. Gasket materials and seals shall be suitable for the fluid used.

3-8.2*

Properly identified, manually actuated devices shall be provided in a readily accessible location to shut off hydraulic pumps in the event of leakage, pipe or hose failure, or fire. These devices shall shut off the hydraulic pump drive system.

3-9* Instrumentation.

3-9.1

Computer rooms and electronic data processing equipment shall meet the requirements of NFPA 75, *Standard for the Protection of Electronic Computer/Data Processing Equipment*, and the protection requirements specified in Chapter 4 of this standard.

3-9.2*

Signal and control wiring or tubing shall be installed to minimize exposure from fuel hazards or physical damage from engine disintegration.

3-9.3

Flow meters or sensing lines containing fuel or oil shall not be located in the control room.

Chapter 4 Fire Protection Requirements

4-1 Engine Test Facility.

4-1.1

Portable fire extinguishers shall be provided throughout the engine test facility. Portable fire extinguishers and their distribution shall meet the requirements of NFPA 10, *Standard for Portable Fire Extinguishers*.

4-1.2

Portable fire extinguishers shall not be located within the engine test cell.

4-1.3

Class B hazards shall be classified as an Extra Hazard in accordance with NFPA 10, *Standard for Portable Fire Extinguishers*.

4-1.4

Class A hazards shall be classified as at least an Ordinary Hazard in accordance with NFPA 10, *Standard for Portable Fire Extinguishers*.

4-1.5

As an alternative to the requirements of 4-1.1 of this section, hand hose lines of one or more of the following types shall be permitted in place of 50 percent of the required portable fire extinguishers:

(a) Water, meeting the requirements of NFPA 14, *Standard for the Installation of Standpipe and Hose Systems*;

(b) Carbon dioxide, meeting the requirements of Chapter 4 of NFPA 12, *Standard on Carbon Dioxide Extinguishing Systems*;

(c) Foam, meeting the requirements of NFPA 11, *Standard for Low-Expansion Foam*;

(d) Dry chemical, meeting the requirements of Chapter 6 of NFPA 17, *Standard for Dry Chemical Extinguishing Systems*.

4-1.5.1 Where hand hose lines are provided, each hose line station shall be located so it is easily accessible.

4-1.6

The engine test facility shall be provided with an alarm and communications system meeting the requirements of 28-3.4 and Section 7-6 of NFPA *101*®, *Life Safety Code*®. In addition, the alarm system shall notify personnel in the control room and engine test cell.

4-1.7*

Where provided, fire detection systems shall meet the requirements of NFPA 72, *National Fire Alarm Code*.

4-2* Engine Test Cell.

4-2.1*

At least one of the following fire protection systems shall be provided to protect each engine test cell:

(a) Carbon dioxide system, meeting the requirements of Sections 5-1 and 5-2 of this standard;

(b) Halon system, meeting the requirements of Sections 5-1 and 5-3 of this standard;

(c) Foam system, meeting the requirements of Sections 5-1 and 5-5 of this standard;

(d) Water spray system, meeting the requirements of Sections 5-1 and 5-6 of this standard;

(e) Water deluge system, meeting the requirements of Sections 5-1 and 5-6 of this standard;

(f) Automatic sprinkler system, meeting the requirements of Sections 5-1 and 5-6 of this standard.

4-2.1.1 Systems (a) through (e) shall have a manual release located within the control room.

4-2.1.2 Systems (a) through (e) shall not be required to be automatically actuated.

4-2.2

Where provided, automatic actuation shall be permitted to be bypassed during engine operation provided the control room is continuously attended. Detection and alarms shall remain in service at all times. Any such bypass function shall be electrically supervised.

4-2.3

A separate fire protection system control valve shall be provided for each engine test cell.

4-2.4

Extinguishing systems for engine test cells shall be designed to compensate for the high airflows encountered during operation and engine rundown time.

4-2.5

When provided, time delay for system discharge shall not be less than that required for safe egress of personnel, but shall be permitted to be extended to compensate for engine rundown time.

4-2.6

Piping, nozzles, and actuation systems shall be located to minimize the extent of physical damage in the event of engine disintegration.

4-3 Control Rooms.

4-3.1

Control rooms constructed of materials that are other than noncombustible or limited combustible as defined in Chapter 2 of NFPA 220, *Standard on Types of Building Construction*, shall be protected by an automatic sprinkler system meeting the requirements of Sections 5-1 and 5-6 of this standard.

4-3.2*

Control rooms constructed of either noncombustible or limited combustible materials as defined in Chapter 2 of NFPA 220, *Standard on Types of Building Construction*, shall be provided with at least one of the following automatic fire protection systems:

(a) Halon 1301 total flooding system, meeting the requirements of Sections 5-1 and 5-3 of this standard;

(b) Automatic sprinkler system, meeting the requirements of Sections 5-1 and 5-6 of this standard.

4-4* Support Rooms.

All support rooms shall be provided with at least one of the following automatic fire protection systems:

(a) Carbon dioxide system, meeting the requirements of Sections 5-1 and 5-2 of this standard;

(b) Halon 1301 system, meeting the requirements of Sections 5-1 and 5-3 of this standard;

(c) Dry chemical system, meeting the requirements of Sections 5-1 and 5-4 of this standard;

(d) Foam system, meeting the requirements of Sections 5-1 and 5-5 of this standard;

(e) Water spray system, meeting the requirements of Sections 5-1 and 5-6 of this standard;

(f) Water deluge system, meeting the requirements of Sections 5-1 and 5-6 of this standard;

(g) Automatic sprinkler system, meeting the requirements of Sections 5-1 and 5-6 of this standard.

Chapter 5 Fixed Fire Protection Systems

5-1 General Design Requirements.

5-1.1

Fire protection system control equipment shall be located outside of the hazard area.

5-1.2

All fire protection system control equipment shall be identified as to the hazard protected, the function performed, and the method of operation for manual controls.

5-1.3

Manual fire protection system controls shall be conveniently located and accessible at all times, including the time of fire.

5-2 Carbon Dioxide Systems.

5-2.1

Carbon dioxide systems shall meet the requirements of NFPA 12, *Standard on Carbon Dioxide Extinguishing Systems*.

5-2.2

The system shall have a connected reserve supply not less than 100 percent of the primary supply arranged for immediate manual discharge.

5-2.3

The actuation of the system shall

(a) Close fuel valves supplying fuel to the protected area; and

(b) Activate alarm devices to warn personnel to evacuate the protected area.

5-2.4

The actuation of a total flooding system shall do the following in addition to the requirements of 5-2.3 of this section:

(a) Provide sufficient time to allow personnel to egress before the extinguishing agent is discharged; and

(b) Shut off ventilating fans and close doors and other openings to minimize the leakage of the extinguishing agent from the protected area.

5-2.5

Closing of doors shall not prevent the safe egress of personnel from the protected area.

5-3 Halon Systems.

5-3.1

Halon systems shall meet the requirements of NFPA 12A, *Standard on Halon 1301 Fire Extinguishing Systems*, or NFPA 12B, *Standard on Halon 1211 Fire Extinguishing Systems*.

NOTE: Halon 1211 and Halon 1301 are included in the "Montreal Protocol on Substances that Deplete the Ozone Layer" signed September 16, 1987. The 1992 amendments to the protocol call for a cessation of production of Halon 1211 and Halon 1301, worldwide.

5-3.2

Halon systems shall have a connected reserve supply not less than 100 percent of the primary supply arranged for immediate manual discharge.

5-3.3

The actuation of the system shall

(a) Close fuel valves supplying fuel to the protected area; and

(b) Activate alarm devices to warn personnel to evacuate the protected area.

5-3.4

The actuation of a total flooding system shall do the following in addition to the requirements of 5-3.3 of this section:

(a) Provide sufficient time to allow personnel to egress before the extinguishing agent is discharged; and

(b) Shut off ventilating fans and close doors and other openings to minimize the leakage of the extinguishing agent from the protected area.

5-3.5

Closing of doors shall not prevent the safe egress of personnel from the protected area.

5-4 Dry Chemical Systems.

5-4.1

Dry chemical systems shall meet the requirements of NFPA 17, *Standard for Dry Chemical Extinguishing Systems*.

5-4.2

The actuation of the system shall

(a) Close fuel valves supplying fuel to the protected area;

(b) Activate alarm devices to warn personnel to evacuate the protected area;

(c) Provide sufficient time to allow personnel to egress before the extinguishing agent is discharged; and

(d) Cause ventilating fans to shut down.

5-5 Foam, High-Expansion Foam, Foam-Water Sprinkler, and Foam-Water Spray

Systems.

5-5.1

Low-expansion foam extinguishing systems shall meet the requirements of NFPA 11, *Standard for Low-Expansion Foam*.

5-5.2

High-expansion foam systems shall meet the requirements of NFPA 11A, *Standard for Medium- and High-Expansion Foam Systems*.

5-5.3

Foam-water sprinkler systems and foam-water spray systems shall meet the requirements of NFPA 16, *Standard on the Installation of Deluge Foam-Water Sprinkler and Foam-Water Spray Systems*.

5-5.4

The actuation of a foam, high-expansion foam, foam-water sprinkler, or foam-water spray system shall

(a) Close fuel valves supplying fuel to the protected area;

(b) Activate alarm devices to warn personnel to evacuate the protected area;

(c) Provide sufficient time to allow personnel to egress before the extinguishing agent is discharged; and

(d) Cause ventilating fans to shut down and doors to close automatically.

5-5.5

In engine test cells only, the total discharge rate shall be calculated on the required density over the total floor area.

5-5.6

In engine test cells only, discharge devices shall be arranged to provide coverage of the hazard area. Discharge devices located at the ceiling shall provide complete coverage over the floor area. Directional discharge devices shall project the foam onto the thrust stand regardless of the discharge device location.

5-6 Water Spray Systems, Water Deluge Systems, and Automatic Sprinkler Systems.

5-6.1

Water spray systems shall meet the requirements of NFPA 15, *Standard for Water Spray Fixed Systems for Fire Protection*.

5-6.2

Water deluge systems and other automatic sprinkler systems shall meet the requirements of NFPA 13, *Standard for the Installation of Sprinkler Systems*.

5-6.3*

In engine test cells, the minimum design discharge density shall be 0.50 gpm per sq ft (0.34 l per sec per sq m) of protected area.

5-6.4

In engine test cells, water supplies shall be capable of meeting the largest demand at the design rate plus hose stream demand for a period of 30 min. Hose stream demand shall be a minimum of 250 gpm (16 L per sec). The hydraulic calculation and the water supply shall be based on the assumption that all sprinklers in the test cell are operating simultaneously.

Chapter 6 Employee Organization for Fire Safety

6-1 General.

6-1.1

All personnel engaged in aircraft engine testing operations and all other persons regularly employed and working around engine test facilities shall be instructed in fire prevention practices as part of their regular training. These personnel shall also be trained in the operation of all portable fire extinguishers and hose line systems provided in the area in which they work.

6-1.2

Selected personnel on each operational shift shall be trained in operation of the fixed fire protection systems provided in the test facility. This training shall be accompanied by a comprehensive explanation of all features of such systems and the area they protect.

6-1.3

Responsibility for fire protection equipment, inspection, and maintenance shall be assigned to key personnel.

Chapter 7 Referenced Publications

7-1

The following documents or portions thereof are referenced within this standard and shall be considered part of the requirements of this document. The edition indicated for each reference is the current edition as of the date of the NFPA issuance of this document.

7-1.1 NFPA Publications.

National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.

NFPA 10, *Standard for Portable Fire Extinguishers*, 1994 edition.

NFPA 11, *Standard for Low-Expansion Foam*, 1994 edition.

NFPA 11A, *Standard for Medium- and High-Expansion Foam Systems*, 1994 edition.

NFPA 12, *Standard on Carbon Dioxide Extinguishing Systems*, 1993 edition.

NFPA 12A, *Standard on Halon 1301 Fire Extinguishing Systems*, 1992 edition.

NFPA 12B, *Standard on Halon 1211 Fire Extinguishing Systems*, 1990 edition.

NFPA 13, *Standard for the Installation of Sprinkler Systems*, 1994 edition.

NFPA 14, *Standard for the Installation of Standpipe and Hose Systems*, 1993 edition.

NFPA 15, *Standard for Water Spray Fixed Systems for Fire Protection*, 1990 edition.

NFPA 16, *Standard on the Installation of Deluge Foam-Water Sprinkler and Foam-Water Spray Systems*, 1991 edition.

NFPA 17, *Standard for Dry Chemical Extinguishing Systems*, 1994 edition.

NFPA 30, *Flammable and Combustible Liquids Code*, 1993 edition.

NFPA 31, *Standard for the Installation of Oil-Burning Equipment*, 1992 edition.

NFPA 54, *National Fuel Gas Code*, 1992 edition.

NFPA 58, *Standard for the Storage and Handling of Liquefied Petroleum Gases*, 1992 edition.

NFPA 70, *National Electrical Code*, 1993 edition.

NFPA 72, *National Fire Alarm Code*, 1993 edition.

NFPA 75, *Standard for the Protection of Electronic Computer/Data Processing Equipment*, 1992 edition.

NFPA 86, *Standard for Ovens and Furnaces*, 1990 edition.

NFPA *101*, *Code for Safety to Life from Fire in Buildings and Structures*, 1994 edition.

NFPA 220, *Standard on Types of Building Construction*, 1992 edition.

7-1.2 Other Publication.

7-1.2.1 ANSI Publication. American National Standards Institute, 1430 Broadway, New York, NY 10018.

ANSI B31.1, *Code for Power Piping*, 1989 edition.

Appendix A Explanatory Material

This Appendix is not a part of the requirements of this NFPA document but is included for informational purposes only.

A-1-3 Approved.

The National Fire Protection Association does not approve, inspect, or certify any installations, procedures, equipment, or materials; nor does it approve or evaluate testing laboratories. In determining the acceptability of installations, procedures, equipment, or materials, the authority having jurisdiction may base acceptance on compliance with NFPA or other appropriate standards. In the absence of such standards, said authority may require evidence of proper installation, procedure, or use. The authority having jurisdiction may also refer to the listings or labeling practices of an organization concerned with product evaluations that is in a position to determine compliance with appropriate standards for the current production of listed items.

A-1-3 Authority Having Jurisdiction.

The phrase "authority having jurisdiction" is used in NFPA documents in a broad manner, since jurisdictions and approval agencies vary, as do their responsibilities. Where public safety is primary, the authority having jurisdiction may be a federal, state, local, or other regional department or individual such as a fire chief; fire marshal; chief of a fire prevention bureau, labor department, or health department; building official; electrical inspector; or others having statutory authority. For insurance purposes, an insurance inspection department, rating bureau, or other insurance company representative may be the authority having jurisdiction. In many circumstances, the property owner or his or her designated agent assumes the role of the authority having jurisdiction; at government installations, the commanding officer or departmental official may be the authority having jurisdiction.

A-1-3 Listed.

The means for identifying listed equipment may vary for each organization concerned with product evaluation, some of which do not recognize equipment as listed unless it is also labeled. The authority having jurisdiction should utilize the system employed by the listing organization to identify a listed product.

A-2-1.4

Analysis should include, but not be limited to

(a) The type of testing to be done (e.g., production, endurance, development/research);

(b) Characteristics of the fuel (e.g., flash point, vapor density, autoignition temperature);

(c) Amount of airflow and whether it is ducted to the engine;

(d) Presence of continuous ventilation;

(e) Fuel quantity in relation to volume of the enclosure;

(f) Maximum fuel pressure, temperature, flow, and delivery system;

(g) Life safety considerations.

Test cells can be subject to an explosion hazard because of the presence of flammable vapors and the confinement of same within the test cell. The potential damage from an explosion will depend on numerous factors, including

(a) The designed pressure resistance of the structure;

(b) The amount of area utilized for inlet and exhaust air;

(c) The amount of explosion venting provided;

(d) The amount of continuous ventilation provided;

(e) The presence of explosion suppression equipment.

Explosion venting, continuous ventilation, and/or explosion suppression should be considered in the design of test cells. The planned use of the cell, the supporting equipment, the type of construction, and the configuration of the cell are some factors to be considered. (*See A-3-5.1.*) The net unobstructed area of engine test cell inlet and exhaust passages can be included in the venting area. Explosion venting could be effected in the cells proper by the use of lightweight roof or wall panels or outward opening doors equipped with resisting devices to prevent the venting device from being projected with chance of injury to personnel or damage to equipment in the event of operation. Guidance for explosion venting is provided in NFPA 68, *Guide for Venting of Deflagrations*. Where the specific design or configuration of a test facility does not allow the use of explosion venting, or allows very minimal explosion venting, consideration should be given to the protection of the structure or specialized equipment by the use of explosion suppression systems. Requirements for explosion suppressions are provided in NFPA

69, *Standard on Explosion Prevention Systems*.

A-2-2

Test cell walls should not form common walls with main manufacturing buildings. Test cells should be located to minimize the exposure from openings such as doors, windows, inlet and exhaust stacks, ventilating ducts, explosion vents, or exhaust pipes to (a) combustible construction or unprotected openings at the same or higher elevation, and (b) utilities such as transformers, overhead transmission lines, overhead service piping, and cooling towers. Where test cells are of light construction, important exposed buildings and utilities should be shielded from the possible disintegration of aircraft engines.

Other walls, ceilings, and floor assemblies comprising the engine test facility should be fire resistive, protected noncombustible, or noncombustible construction. The type of construction utilized in test buildings is determined to an extent by their proximity to main buildings or vital utilities.

A-3-1.1

Parts or foreign objects that are located in front of a turbine engine or in other locations where they might be ingested into an engine are likely to cause damage to the engine or to a critical system and cause a fire. Test cell operating procedures should therefore include a thorough inspection of the test cell and engine before engine starting to check for proper safety of parts and to eliminate foreign objects (e.g., tools, lockwire, nuts, bolts, washers, stones).

A-3-2.1

Test cells and support rooms not containing flammable or combustible liquid handling systems might also require drainage systems to effectively dispose of water used for engine washing, exhaust gas cooling system malfunctions, rainwater, and water discharged from fire protection systems. Test cell floor drains should be located, where possible, downwind of probable fuel spill locations to minimize the pounding effect of high test cell air velocity. Requirements of federal, state, and local environmental agencies should be consulted.

A-3-2.4

Where deluge sprinkler systems are installed, the capacity of the drainage system can be determined by the sprinkler design rate increased by an appropriate correction for maximum main pressure. Exhaust gas cooling water rates need not be included in the determination of peak drainage if an adequate emergency shutoff system or separate drainage system is provided.

A-3-2.5

All drain traps should be provided with an automatic reseal system.

A-3-3.3

It is common practice to locate limit switches for elevating work platforms below the floor level. An accidental shorting or grounding of these circuits should not allow the elevator to move or overrun, which could result in damage to engine fuel lines and ensuing fire.

A-3-3.8

The failure of electric power supply to a test cell might deprive the operator of control of the engine, resulting in possible engine damage and ensuing fire. Battery power or other means should be provided in order to properly operate the engine during such failures.

A-3-4.1

Heating and cooling systems used in conjunction with engine test facilities require careful design and installation because of the magnitude of the hazards, the complexity of the operations, and the operational importance of the facility.

A-3-4.2

Surface temperatures of exposed heating elements should not equal or exceed the minimum auto-ignition temperature of the most hazardous flammable liquid or gas used.

A-3-4.3

Direct cooling systems are preferred to systems that utilize extensive ductwork that penetrates cell walls.

A-3-4.4

Test cell inlet preheaters used to simulate hot inlet air conditions should preferably use steam or a liquid heat exchange medium. Auxiliary fans to allow pre- and post-operation purging prior to lightoff and after running might be needed. Four complete cell air changes should be made before purging is considered complete. Preheaters utilizing gaseous fuel should have continuous gas detectors sampling all areas subject to flammable vapor accumulation. Gas detection systems should be interlocked to shut off gas and sound an alarm at 25 percent of the lower flammable limit.

A-3-5.1

Forced air ventilation at the rate of 1 cu ft per min per sq ft (0.005 cu m per sec per sq m) of floor area should be provided in engine test areas when engines are not running.

A-3-6.2

An additional fuel shutoff valve should be located before any flexible connection to the engine to isolate fuel inside the test cell if the quantity contained between the test cell wall and the engine is significant.

A-3-6.3

Consideration should be given to the automatic operation of the emergency fuel safety shutoff valve by one or more of the following methods:

(a) Operation of the fire protection system;

(b) On actuation of heat sensing devices;

(c) Excess fuel flow.

A-3-8.1

Many hydraulic systems utilize combustible oil under high pressure to transmit power or motion. The use of combustible hydraulic oils presents a potential fire and explosion hazard. Atomization of such fluids greatly increases the ease of ignition.

Use of hydraulic fluids with low fire hazard potential is encouraged. Such fluids include water-glycol, halogenated-hydrocarbon, phosphate-ester, or water-oil-emulsion types. When converting from one hydraulic fluid to another, the entire hydraulic system should be thoroughly cleaned, and seals, packings, valves, or pumps should be changed to prevent leakage. Equipment and fluid manufacturers should be consulted for proper conversion procedures in these nonengine related hydraulic systems.

Flexible connectors and hoses should be avoided.

A-3-8.2

The hydraulic line should also be shut off by these devices to minimize fluid leakage.

A-3-9

Instrumentation is an essential part of every engine testing facility and can include flow meters, pressure and temperature sensors, indicators, gauges, transducers, thrust and position indicators, vibration monitors, etc.

A-3-9.2

Control instrumentation should be arranged so that its failure will not introduce a hazard. Where combustible pneumatic tubing is grouped in cabletrays or troughs, additional fire protection might be needed to prevent extensive damage to the tubing system.

A-4-1.7

When a fire detection system is installed to sound an alarm or actuate a fire extinguishing system, the detection system design should consider airflows, engine location, heat sources from engine, and whether or not the engine is being continuously observed. In test facilities where airflow velocities in excess of 25 ft/sec (7.6 m/sec) are expected, optical detection should be used.

A-4-2

Where supplementary fire protection systems are provided for engine protection in addition to the required engine test cell fire protection, they should be designed and installed in an approved manner.

The following are the more common supplementary systems used for engine protection:

(a) *Carbon dioxide spurt system.*

1. A carbon dioxide spurt system is usually a manually actuated fixed-pipe system designed to locally apply carbon dioxide to an engine on an intermittent basis, or continuously by the operator. A spurt system can have its own agent supply or can be supplied from a total flooding or local application carbon dioxide system. Such a system is intended to provide a means for quick knockdown of fires in or around the engine while the engine is operating. There are usually no interlocks to shut down fuel flows, alarms, etc.

2. Pipings and fittings should conform to the applicable provisions of NFPA 12, *Standard on Carbon Dioxide Extinguishing Systems*.

3. The primary supply and connected reserve supply should each be designed to provide a continuous discharge for a minimum of three minutes.

(b) *Steam fire protection systems.* Steam extinguishes a fire in a manner similar to inert gases. In order to maintain steam in its true form at normal atmospheric temperatures and pressures and prevent its condensing to water vapor, very large quantities should be discharged at one time. This makes steam impractical for total flooding of a large test cell. It can be effective for engine fires when discharged within an enclosing cowl, when injected into cavities within the engine, or when injected into the main inlet air stream or into the tailpipe of an engine. Such factors as boiler maintenance, standby boilers, boiler fuel availability, normal peak steam demand, boiler feedwater availability, and availability of alternate emergency fire protection services should be considered in analyzing steam source requirements or suitability. The following guidelines are offered:

1. Steam can be used as an effective supplementary system for engine protection, provided steam is available in sufficient quantities whenever the test cell is in operation.

2. Piping for the distribution of steam from the source to the point of use should follow ANSI B31.1, *Code for Power Piping*, as applicable.

3. The steam flow rate should be sufficient to achieve a ratio of steam volume to total protected volume of 50 percent within 30 seconds. The steam supply should be capable of maintaining that concentration until the fire has been extinguished. Steam discharge to atmosphere of not less than 15 psi (103 421 Pa) can be approximated by the formula

$$W = 0.7A\,(P + 15)$$

where:

W = pounds of steam per minute

0.7 = constant including an orifice coefficient

A = orifice area (square inches)

P = gauge pressure at outlet (pounds per square inch)

For more precise determination of required orifice size, or when upstream and downstream pressure conditions are different from the above, consult a standard textbook on steam flow control.

4. The system should not be automatically actuated. Personnel hazards should be considered prior to manual actuation.

5. Steam condensate traps and lines should be provided to bleed off liquid and allow only vapor to be directed to the protected area.

6. The steam system should be inspected and tested at least semiannually.

A-4-2.1

Each agent has its advantages and disadvantages, and the choice of agent or combination of agents should be made only after careful consideration of the objective of the protection and the conditions of each individual installation. Some of the factors pertinent to each agent are

(a) *Water.* Water, particularly in spray form, is an effective agent in controlling or extinguishing kerosene-grade (e.g., JET A or A-1; JP-5 or JP-8) jet fuel fires. It is not an effective extinguishing agent for fuels containing gasoline (e.g., JET B; JP-4). The principal advantage of water is its superior cooling capacity. Other advantages are adequate supply for continuous discharge over long periods, ease of piping, and low cost. Disadvantages are drainage requirements and possible water damage to the test engine, electrical devices, wiring, and instrumentation. Deluge systems are considered more appropriate than closed head automatic sprinklers due to their speed of operation and simultaneous discharge from all nozzles. Automatic sprinklers can be effectively used in small test cells [600 sq ft (56 m^2) or less] where it is likely that all sprinklers would fuse at the same time or as a backup to a manual water spray or other manual system.

(b) *Carbon dioxide.* Carbon dioxide is an effective extinguishing agent for flammable liquid fires when applied in sufficient concentration. Its principal advantage is lack of agent damage. Other advantages are no cleanup and relatively low cost for recharging the system. Disadvantages are the need to evacuate personnel from a protected area, limited supply of agent, leakage of agent from a protected space, and lack of significant cooling effect.

(c) *Foam.* Foam is an effective extinguishing agent for all aviation fuels. It is most applicable for fires involving large spills. Other advantages are (1) the ability to cover large fuel spills before they become ignited, and (2) its insulating qualities. Disadvantages are lack of effectiveness on three-dimensional fires (e.g., fuel flowing from an elevated source), cost of agent, and cleanup. Foam systems are not effective on fires involving flammable gases.

(d) *Dry chemical.* Dry chemical extinguishing agents are effective for flammable liquid and gaseous fires. They have rapid knockdown and extinguishing capability. Dry chemical extinguishing agents are not considered desirable for test cell coverage due to extensive cleanup required and potential damage to electrical contacts and engine parts.

(e) *Halon.* Halon can be used for extinguishing fuel spill fires and engine fires and has the ability to extinguish or suppress fires in surface-burning Class A materials as well as extinguishing Class B fires and being safe to use on Class C (electrical) fires. The compatibility of the agents with engine parts should be investigated since the decomposition products might be corrosive. The only halons recommended for test facility protection are Halon 1301 and Halon 1211. Both agents require less extinguishing concentrations than carbon dioxide, resulting in smaller piping and less agent storage.

See NFPA 12A (Halon 1301) and NFPA 12B (Halon 1211) for more descriptive information.

A-4-3.2

See A-4-2.1.

A-4-4

See A-4-2.1.

A-5-6.3

Because of the nature of the test cell fire potential, deluge systems are considered more appropriate than automatic sprinklers due to their speed of operation and simultaneous discharge of all nozzles; however, automatic sprinklers can be used

(a) In small cells [600 sq ft (56 m^2) or less] where it is likely that all sprinklers would fuse at the same time; or

(b) As a backup to a manual water spray or other manual system.

Appendix B Referenced Publications

B-1

The following documents or portions thereof are referenced within this standard for informational purposes only and thus are not considered part of the requirements of this document. The edition indicated for each reference is the current edition as of the date of the NFPA issuance of this document.

B-1.1 NFPA Publications.

National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.

NFPA 12, *Standard on Carbon Dioxide Extinguishing Systems*, 1993 edition.

NFPA 12A, *Standard on Halon 1301 Fire Extinguishing Systems*, 1992 edition.

NFPA 12B, *Standard on Halon 1211 Fire Extinguishing Systems*, 1990 edition.

NFPA 68, *Guide for Venting of Deflagrations*, 1994 edition.

NFPA 69, *Standard on Explosion Prevention Systems*, 1992 edition.

B-1.2 Other Publication.

B-1.2.1 ANSI Publication. American National Standards Institute, 1430 Broadway, New York, NY 10018.

ANSI B31.1, *Code for Power Piping*, 1989 edition.

Formal Interpretation

NFPA 423

Construction and Protection of Aircraft Engine Test Facilities

1994 Edition

Reference : 5-6.3
F.I. 89-1 (NFPA 423)

Question 1: For automatic sprinkler system protection for an engine test cell, is the "protected area" the entire floor area?

Answer: Yes.

Question 2: For water deluge system protection for an engine test cell, is the "protected area" the entire floor area?

Answer: Yes.
Issue Edition: 1989
Reference: 5-6.3
Issue Date: April 18, 1994
Effective Date: May 8, 1994

NFPA 424

1996 Edition

Guide for Airport/Community Emergency Planning

1996 Edition

This edition of NFPA 424, *Guide for Airport/Community Emergency Planning*, was prepared by the Technical Committee on Aircraft Rescue and Fire Fighting and acted on by the National Fire Protection Association, Inc., at its Annual Meeting held May 20–23, 1996, in Boston, MA. It was issued by the Standards Council on July 18, 1996, with an effective date of August 9, 1996, and supersedes all previous editions.

Changes other than editorial are indicated by a vertical rule in the margin of the pages on which they appear. These lines are included as an aid to the user in identifying changes from the previous edition.

This edition of NFPA 424 was approved as an American National Standard on July 26, 1996.

Origin and Development of NFPA 424

The Subcommittee on NFPA 424 started work on this document in 1976. It was submitted to the Association at the 1978 Fall Meeting and released as the first edition on January 25, 1979.

The complete text was rewritten in 1986 in an informational format. The document was again rewritten in 1991. This edition is a partial revision. The work of revising this document was accomplished with the assistance of a Task Group appointed by the chair. The Task Group on Airport/Community Emergency Planning was comprised of the following members:

Davis R. Parsons, Chair, Los Angeles City Fire Dept., CA; Brian Boucher, Canadian Air Line Pilots Assn., ON, Canada; Derek K. G. Dodwell, Civil Aviation Authority, England; John J. O'Sullivan, British Airways, England; John X. Stefanki, John X. Stefanki, Inc., CA; Ronald O. Wikander, Lockheed Aeronautical Systems Co., GA; Larry E. Williams, Emergency Response Training Academy, Inc., AR; Miles Young, US Air Force, FL.

Technical Committee on
Aircraft Rescue and Fire Fighting

Brian Boucher, *Chair*
Canadian Air Line Pilots Assn., Canada

Rep. Canadian Air Line Pilots Assn.

Robert J. Donahue, *Secretary*
Massport Fire Dept., MA

John Cedric Black, BAA plc, England

Booker T. Burley, Hartsfield Atlanta Int'l Airport, GA

Ralph Colet, John Russo Industrial Inc., CA

Robert L. Darwin, U.S. Dept. of the Navy, DC

Charlie L. Duncan, Atlanta Fire Dept., Atl. Airport, GA

Fred B. Goodnight, Amerex Corp., AL
Rep. Fire Equipment Mfrs.' Assn. Inc.

B. V. Hewes, Airport Safety Services, GA

Paul O. Huston, Paul O. Huston, PE & Assoc., AL

D. Steve Kiernan, Chubb Nat'l Foam, Inc., PA

L. M. Krasner, Factory Mutual Research Corp., MA

Dave Lenz, Oshkosh Truck Corp., WI

Daniel A. Nommensen, Emergency One, Inc., FL

John J. O'Sullivan, British Airways, England

David R. Parsons, Los Angeles City Fire Dept., CA

Gaetan Perron, Dept. of Nat'l Defence, Canada

Lee W. Prazer, Akron Brass Co., OH

Robert G. Relyea, ARFF Working Group, TX

Robert E. Reyff, U.S. Air Force, FL

Paul R. Robinson, Kennesaw, GA
Rep. Airline Pilots Assn.

John F. Rooney, Tucson, AZ

Joseph L. Scheffey, Hughes Assoc. Inc., MD

John M. Schuster, 3M Co., MN

John X. Stefanki, John X. Stefanki Inc., CA

Ronald O. Wikander, Lockheed Aeronautical Systems Co., GA

Larry E. Williams, Emergency Response Training Academy, Inc., AR

Joseph A. Wright, Federal Aviation Administration Tech Ctr., NJ

Alternates

D. L. J. Dunbar, Simon Access (UK) Ltd, England
(Vot. Alt. to SGSL Rep.)

Frank M. E. Hughes, British Airways, England
(Alt. to J. J. O'Sullivan)

Thomas E. McMaster, Los Angeles City Fire Dept., CA
(Alt. to D. R. Parsons)

Richard E. Ottman, 3M Co., MN
(Alt. to J. M. Schuster)

Frank H. Schneck, Jr., Emergency One, Inc., FL
(Alt. to D. A. Nommenson)

William S. Weeks, Airline Pilots Assn., NC
(Alt. to P. R. Robinson)

Nonvoting

Derek K. G. Dodwell, Civil Aviation Authority, England

Gary Hammack, U.S. Nat'l Transportation Safety Board (TE-10), DC

Thomas J. Lett, Albuquerque Fire & Safety Assoc. Inc., NM
(Member Emeritus)

John E. Lodge, Lodge Fire Protection Consultancy Ltd, England
(Member Emeritus)

Lawrence D. Roman, U.S. Nat'l Transportation Safety Board, DC

David F. Short, Carmichael Int'l Ltd, England

Committee Scope: This Committee shall have primary responsibility for documents on the criteria for aircraft rescue and fire fighting services and equipment, procedures for handling aircraft fire emergencies, and for specialized vehicles used to perform these functions at airports with particular emphasis on saving lives and reducing injuries coincident with aircraft fires following impact or aircraft ground fires. Develops aircraft fire investigation procedures as an aid to accident prevention and the saving of lives in future aircraft accidents involving fire.

NFPA 424
Guide for
Airport/Community Emergency Planning

1996 Edition

NOTICE: An asterisk (*) following the number or letter designating a paragraph indicates explanatory material on that paragraph in Appendix A.
Information on referenced publications can be found in Appendix C.

Chapter 1 Administration

1-1 Scope.

This guide describes the elements of an airport/community emergency plan that require consideration before, during, and after an emergency has occurred. The scope of the airport/community emergency plan should include command, communication, and coordination functions for executing the plan. Throughout this document, the airport/community emergency plan will be referred to as the "Plan."

1-2 Purpose.

This guide was written to inform airport and adjacent community authorities of current emergency planning techniques and procedures that result in the efficient utilization of personnel from all involved organizations and agencies to provide effective delivery of emergency services in the event of an aircraft related emergency. Jurisdictional problems previously identified in actual emergencies or emergency plan exercises point out the necessity of resolving the conflicts as part of the development of the Plan.

Recommendations contained herein are not intended to conflict with any local or state regulations. One of the principal purposes of this document is to alert all participants to conflicts that can exist due to multijurisdictional factors, such as conflicts between state and local regulations.

1-3 Definitions.

A wide variety of terms are in use throughout the world to describe facilities, procedures, and services related to airports. Wherever possible the terms used in this guide are those that have the widest international use. When the following terms are used in this guide they have the following meaning:

Aircraft Accident. An occurrence associated with the operation of an aircraft that takes place between the time a person boards the aircraft with the intention of flight and the time such person has disembarked, in which a person suffers death or serious injury as a result of the occurrence or in which the aircraft receives substantial damage.

Aircraft Emergency Exercise. Testing of the emergency plan and review of the results in order to improve the effectiveness of the plan.

Aircraft Incident. Any occurrence associated with the operation of an aircraft that is not considered an “aircraft accident.”

Aircraft Operator. A person, organization, or enterprise engaged in, or offering to engage in, aircraft operation.

Airline Coordinator. A representative authority delegated by an airline to represent its interests during an emergency covered by this guide.

Airport Air Traffic Control. A service established to provide air and ground traffic control for airports.

Airport/Community Emergency Plan. Establishment of procedures for coordinating the response of airport services with other agencies in the surrounding community that could be of assistance in responding to an emergency occurring on, or in the vicinity of, the airport.

Airport Control Tower. A unit established to provide air traffic control service for airport traffic.

Airport Flight Information Service. Air traffic control services units that provide airport flight information service, search and rescue, alerting service to aircraft at noncontrolled airports, and assistance to aircraft in emergency situations.

Airport Manager. The individual having managerial responsibility for the operation and safety of an airport. The manager can have administrative control over aircraft rescue and fire fighting services but normally does not exercise authority over operational rescue and fire matters.

Airside (Airport Operational Area). The movement area of an airport, adjacent terrain, and buildings or portions thereof, access to which is controlled.

Approved.* Acceptable to the authority having jurisdiction.

Authority Having Jurisdiction.* The organization, office, or individual responsible for approving equipment, an installation, or a procedure.

Biological Agents. Living organisms that can be dangerous to human, animal, or plant life upon release.

Care Area. Location where initial medical care is given to injured.

Collection Area. Location where seriously injured are collected initially.

Command Post (CP). The location at the scene of an emergency where the incident commander is located and where command, coordination, control, and communications are centralized.

Emergency Medical Technician (EMT). A person trained to administer emergency medical treatment more advanced than basic first aid.

Emergency Operations Center. A fixed, designated area to be used in supporting and coordinating operations during emergencies.

Grid Map. A plan view of an area with a system of squares (numbered and lettered) superimposed to provide a fixed reference to any point in the area.

Holding Area. Location where the apparently uninjured aircraft occupants are transported.

Incident Command System (ICS). The combination of facilities, equipment, personnel, procedures, and communications operating within a common organizational structure with responsibility for the management of assigned resources to effectively accomplish stated objectives pertaining to an incident.

Incident Commander (IC). The person in overall command at an emergency.

In-Flight Emergency. Those emergencies that affect the operational integrity of an aircraft while in flight. The seriousness of these emergencies can be defined by using alert status guidelines stated in FAA terms.

Inner Perimeter. That area which is secured to allow effective command, communication, and coordination control and to allow for safe operations to deal with an emergency, including the immediate ingress and egress needs of emergency response personnel and vehicles.

Investigation. A process conducted for the purpose of accident prevention that includes the gathering and analysis of information, the drawing of conclusions, including the determination of cause(s) and, where appropriate, the making of safety recommendations.

Medical Transportation Area. That portion of the triage area where injured persons are staged for transportation to medical facilities under the direct supervision of a medical transportation officer.

Mobile Emergency Hospital (MEH). A specialized, self-contained vehicle that can provide a clinical environment that enables a physician to provide definitive treatment for serious injuries at the accident scene.

Moulage. A reproduction of a skin lesion, tumor, wound, or other pathological state. Applied for realism to simulate injuries in emergency exercises.

Mutual Aid. Mutual aid is synonymous with “mutual assistance,” “outside aid,” “memorandums of understanding,” “letters of agreement,” or other similar agreements, written or not, that constitute an agreed reciprocal assistance plan between emergency services.

Outer Perimeter. That area outside of the inner perimeter that is secured for immediate-support operational requirements, free of unauthorized or uncontrolled interference.

Paramedic. A medical technician who has received extensive training in advanced life support and emergency medicine. These personnel are usually permitted to administer intravenous fluids and other drugs that can arrest a life-threatening physiological condition.

Rendezvous Point. A prearranged reference point, i.e., road junction, crossroad, or other specified place, where personnel/vehicles responding to an emergency situation initially proceed to receive directions to staging areas or the accident/incident site or both.

Specialty Emergency Exercise. One or more specialty agencies fully involved in an exercise to test or give the agency practice in its specialty.

Stabilization. The medical measures used to restore basic physiologic equilibrium to a patient, to facilitate future definitive care, in order to ensure survival.

Staging Area. A prearranged, strategically placed area, where support response personnel, vehicles, and other equipment can be held in an organized state of readiness for use during an emergency.

Triage. The sorting of casualties at an emergency according to the nature and severity of their injuries.

Triage Tag. A tag used in the classification of casualties according to the nature and severity of their injuries.

Chapter 2 Elements of Emergency Planning

2-1* General.

2-1.1

The Plan should describe the coordination of the actions to be taken in an emergency occurring at an airport or in its vicinity. It should be built around an incident command system compatible with provider agencies.

2-1.2

“During the emergency” considerations depend on the exact nature or location of the incident or both. The location should dictate the agency responsible for management of the emergency. As the nature of the incident changes from emergency operations to the investigative phase, the appropriate investigative agency should assume command and responsibility for the incident scene. All agencies responding to the incident should know, in advance, their respective roles and responsibilities and who they report to and who reports to them.

2-1.3

“Post-emergency” considerations also should be given considerable attention. Transition of authority and other legal factors should be discussed and preplanned. Consideration should be given to the restoration of protective services in order to permit continuation of normal airport/aircraft operations and public protection that was disrupted by the emergency.

2-1.4

The recommendations contained in this document are based on the requirement that rescue of aircraft occupants and other related accident victims is the primary operational objective. Effective operations require a great deal of preplanning and regular exercises that provide an opportunity for realistic training of personnel from all agencies that will be involved in the incident.

2-1.5

It is crucial that response agencies consider local weather conditions and nighttime operations while developing details of the Plan. For example, low temperatures can freeze medical solutions or tubing during protracted extrication operations. Severe weather conditions also can negatively affect fire fighting foam solution.

Precautions should be taken, where necessary, to mitigate weather induced physical problems such as hypothermia and dehydration. Such considerations should apply to emergency personnel, as well as victims of the accident.

2-1.6 Amendment of the Plan.

2-1.6.1 The airport authority should maintain the master records of the Plan and transmit to each participating agency amendments, additions, and revisions as appropriate.

2-1.6.2 The scope of the Plan should include command, communication and coordination functions for executing the Plan. The Plan should be constructed using a modular and severable format in order to facilitate revisions of specific elements without having to rewrite the entire Plan. The Plan should be reviewed on an annual basis by all participants. The review should include a comprehensive analysis of lessons learned from training sessions, incidents, geographical and physical changes, legal and technical changes, and other factors that can influence the adequacy of the Plan.

2-1.7 Training Costs.

The costs of a major training exercise can be a considerable factor for even the smallest of airports. Budgetary planning for training costs should include salaries for personnel, consumables such as fuel, extinguishing agent, medical supplies, legal advice, and other necessary items, such as food for all participants.

2-2* Types of Emergencies and Emergency Alerts.

2-2.1

Many different types of emergencies can strike a community. However, when creating an airport/community emergency plan, the focus should be on aircraft related incidents. Preparation for other types of emergencies, such as floods or earthquakes, should be addressed in preplanning documents built around the special nature of those incidents.

2-2.2

Most aircraft accidents occur within the airport operational area. However, experience has shown that the most devastating aircraft accidents have been those that occur off-airport, involving structures. It is therefore necessary to design a plan that provides for the needs of both.

2-3 Essential Elements of the Plan.

The following should be considered as essential elements of an airport/community emergency plan:

(a) Establishment of formal instruments/agreements/joint powers, etc., to initiate development and implementation of the Plan;

(b) Detailed planning for 24-hour response, communications, logistics, etc;

(c) Agreement for incident command and control systems and procedures;

(d) Funding for practice;

(e) Regular and “as needed” Plan updates; and

(f) Public relations efforts that bring popular and political support to maintaining readiness.

Chapter 3 Agencies Involved

3-1 Agencies.

3-1.1

The Plan should have an up-to-date list of all agencies involved. In addition to agency identification, the list should include current telephone numbers and names of primary contact persons. This list should be reviewed, revised as necessary, and distributed to all agencies on a regular basis.

3-1.2

The first step in a viable airport emergency plan is to have the cooperation and participation of all concerned airport/community authorities and agencies. Those that should be involved are:

(a) Air traffic control services;

(b) Rescue and fire fighting services (departments);

(c) Police/security services;

(d) Airport authority;

(e) Emergency medical services, including ambulance services;

(f) Hospitals;

(g) Aircraft operators;

(h) Communication services;

(i) Airport rescue coordination center;

(j) Transportation authorities (land, sea, and air);

(k) Hospital coordination center;

(l) Civil defense;

(m) Mutual aid agencies;

(n) Military;

(o) Harbor patrol and/or coast guard;

(p) Clergy;

(q) Public information office/news media;

(r) Veterinary service;

(s) Civil engineering contractors;

(t) Post office;

(u) Environmental Protection Agency (EPA);

(v) Customs;

(w) Public utilities; and

(x) Mental health agencies.

3-2 Air Traffic Control Services.

For emergencies involving aircraft, the airport control tower (or airport flight service station) is required to contact the rescue and fire fighting service and provide information on the type of emergency, such as the type of aircraft, number of persons on board, fuel quantity, and location of the accident, if known. After the initial call, mutual aid agencies should be provided the airport grid map reference, rendezvous point, and where necessary, the airport entrances to be used. Alternately, this function can be assigned by the Plan, either in whole or in part, to another organization or unit. The Plan also may specify that air traffic control services is responsible for initiating the notification of local fire departments and other appropriate agencies in accordance with procedures established in the Plan. The Plan can assign this function to another agency, such as the local fire department dispatching center, but it is very important that this extremely crucial function be well-documented and understood by all concerned.

3-3 Rescue and Fire Fighting Services (Departments).

3-3.1*

The primary responsibility of airport rescue and fire fighting personnel is to save lives. Property endangered by aircraft incidents and accidents occurring on or near the airport should be preserved as far as practical. To achieve this objective, fire control normally is defined as “securing” the area to prevent any reignitions. There can be aircraft accidents, however, where fire does not occur or where the fire is rapidly extinguished. In every case each action taken is aimed at providing the most immediate attention possible to survivors of the accident.

3-3.2

Rescue and fire fighting personnel should receive emergency medical training that meets the minimum standards of their state and local jurisdictions. The stabilization of seriously injured victims can depend entirely upon these first-arriving personnel. Coordination with other responding personnel having advanced medical expertise (paramedics and medical doctors) should be addressed in the Plan.

3-3.3

The fire fighting officer in command should be identified by a standard distinctive uniform. In addition, the Plan should provide for a highly visible vest or other apparel with reflective lettering, front and back, that reads “INCIDENT COMMANDER.”

3-3.4

Only fire fighting and rescue personnel wearing approved fire fighting protective clothing and equipment should be allowed in close proximity to an aircraft accident site [300 ft (100 m) from any point on the aircraft or any fuel spillage is usually considered a safe distance].

3-4 Police/Security Services.

3-4.1

In an airport emergency, it should be expected that the first police or security officer to arrive at the scene will initiate site security procedures and request reinforcement as needed. It should be expected that these responsibilities will be spelled out in the Plan, identifying the responsible law enforcement agency for the accident site and providing for a smooth transition of command should responsibility for site security shift from one agency to another.

3-4.2

Congestion-free ingress and egress roads should be established immediately for emergency vehicles. The security services, police force, or other appropriate local authorities should be expected to ensure that only persons with specific tasks are allowed at the scene of the accident, and they also should be expected to route the normal traffic away from or around the accident site.

3-4.3

The Plan should provide for the prevention of unauthorized access to the accident site and for preserving the site undisturbed for investigation purposes.

3-4.4

A mutual aid program should be instituted between all potentially involved security agencies, e.g., airport, city, local, and governmental security forces; mail inspectors; and, where appropriate, military police and customs officials.

3-4.5

A method of easy identification of responding emergency personnel should be implemented at security check points to ensure that appropriate emergency personnel have immediate access to the accident site. “Emergency Access” identification can be preissued by the airport authority to emergency personnel for use during an emergency.

3-4.6

In many cases it is not possible or practicable for vehicles of mutual aid fire departments, ambulances, etc., to proceed directly to the accident/incident site. It should be essential that the emergency plan include procedures for meeting at a designated rendezvous point or points. A rendezvous point also can be used as a staging area where responding units can be held until needed at the accident site. Suitable accommodation should be provided at the rendezvous point(s) for the rendezvous point officer to facilitate the briefing of incoming officers in charge of supporting services. Adequate telephone and radio provisions should be available. Those controlling the rendezvous point should also consider the suitability of vehicles to adverse terrain conditions at the accident site in order to prevent obstruction of the access route by disabled vehicles. Staging of vehicles can prevent traffic jams and confusion at the accident scene.

3-4.7

To easily identify and distinguish the security/police officer in command, a blue, industrial hard hat and blue, highly visible apparel, such as a vest or coat, should be worn, with reflective lettering "POLICE CHIEF" displayed front and back.

3-5 Airport Authority.

3-5.1

The airport authority is responsible for establishing, promulgating, and implementing the Plan and designating a person to take charge of the overall operation at the command post. The Plan should call for the airport authority to ensure that the information on names and telephone numbers of offices or people involved in an airport emergency is kept up-to-date and distributed to all concerned. Coordination of all agencies responding to an emergency is expected to be carried out by the airport authority. It also should set up necessary meetings of the airport emergency plan coordinating committee, composed of key personnel from participating agencies for critique of the Plan, after it has been tested or implemented. The airport authority should be responsible for closing the airport, or part of it, and ensuring that aircraft operations are resumed only when circumstances permit aircraft to operate safely without interfering with rescue activities.

3-5.2

The airport operations officer in charge should be identified by an international orange hard hat and a highly visible vest or other apparel with reflective lettering, front and back, that reads “AIRPORT ADMINISTRATION.”

3-6 On-Scene Medical Services.

3-6.1

The purpose of medical services is to provide triage, medical care, and transportation to accident victims.

3-6.2

It is essential that the medical aspects of the Plan be integrated with other local community emergency plans and agreements.

3-6.3

A medical coordinator should be assigned to assume command of the emergency medical operations at the accident site. In some cases, it may be necessary to appoint an interim medical coordinator, who will be relieved when the designated medical coordinator arrives. An interim medical coordinator should be assigned by the airport rescue and fire fighting command personnel.

3-6.4

Medical and ambulance services can be an integral part of the airport services, particularly whenever an ambulance service is a part of the airport's rescue and fire fighting service. Whenever medical and ambulance services are not available at the airport, prearrangement with local, private, public, or military medical and ambulance services should be made. The plan should ensure the dispatch of a satisfactory assignment of personnel, equipment, and medical supplies. To ensure a rapid response, the plan can include arrangements for land, sea, and airborne transportation of medical services to the scene, and the subsequent transportation of persons requiring immediate medical care. Prearrangements are necessary to ensure the availability of doctors and other medical personnel for all airport emergencies.

3-6.5

The Plan should designate a medical transportation officer whose responsibilities would include:

(a) Alerting hospitals and medical personnel to the emergency;

(b) Directing transportation of casualties to hospitals properly suited to the particular injury;

(c) Accounting for casualties by recording route of transportation, hospital transported to, and casualty's name and extent of injuries;

(d) Advising hospitals when casualties are en route; and

(e) Maintaining contact with hospitals, medical transportation, the senior medical officer, on-scene command post, and the command post.

3-7 Hospitals.

3-7.1

Participating hospitals should have contingency emergency plans for blood donations and to provide for mobilization of necessary medical trauma teams to the accident site in the shortest possible time. Availability of qualified personnel and adequate facilities at the hospitals are vital. Therefore, it is important to establish in advance an accurate list of surrounding hospitals classified according to their effective receiving capacity and specialized features, such as neurosurgical ability or burn treatment.

3-7.2

The distance from the airport and the ability to receive helicopters should be considered. Reliable two-way communication between the incident command post and these entities is important. The alert of an aircraft accident should be made to a single medical authority/agency, which then alerts all appropriate facilities according to a local medical communications network.

3-7.3

It is essential that hospitals continually communicate through a central control point to facilitate distribution of critically injured patients. Information regarding availability of a specific trauma center, operating room, and ward space should be collected at a central control point, designated in the Plan, and disseminated to the medical transportation officer at the scene.

3-8* Aircraft Operators.

3-8.1*

The aircraft operator/company of an aircraft involved in an accident should be expected to provide full details of aircraft-related information, such as the number of persons on board, fuel, and cargo information. This information is vital to the incident commander and can influence the tactics and strategies used to deal with the emergency.

3-8.2

Aircraft operators also should be responsible for providing first arrangements for any uninjured survivors who need to continue their journey or require accommodation or other assistance. They also might be responsible for contacting deceased passengers' next of kin. Clergy, police, international relief agencies (Red Cross, etc.), and mental health agencies will normally assist in the accomplishment of this task.

3-8.3

The proper disposition of all cargo, mail, and baggage aboard an aircraft involved in an accident is the responsibility of the aircraft operator. Permission to remove these items from the aircraft may be granted by the incident commander after the emergency has been abated and the requirements of the accident investigators have been met.

3-9 Government Authorities. In order to avoid conflict and confusion between participants, the airport emergency plan should clearly define the obligation, controls, and limitations placed on the airport authority by government agencies. Post-accident investigation, unlawful seizure of aircraft, bomb threats, and bombings can fall into jurisdictions other than that of the airport authority.

3-10 Communication Services.

Arrangements should be made to provide all airport agencies involved in an emergency with two-way communication capabilities. The Plan also should provide an adequate communication network to be maintained with the off-airport agencies responding to an emergency. The Plan should call for the command post and emergency operations center to have the capability of freely communicating with all participating agencies. Cellular telephones can be extremely effective. Amateur, military, and civil defense radio networks are worth considering as a back-up.

3-11 Airport Tenants.

Airport tenants and their employees should be considered a prime source of readily available equipment and manpower who may have intimate knowledge of the airport and aircraft. They can be invaluable, especially if their backgrounds include medical training, food preparation, or transportation. It is important that these persons be deployed under supervision and assigned specific functions to avoid duplication of efforts and the possibility of disrupting other emergency operations.

3-12 Transportation Authorities (Land, Sea, Air).

3-12.1

In an emergency, vehicles are needed to carry out rescue operations, transport personnel, and haul supplies and debris. Responsibility for the control of vehicles to be used during an emergency should be assigned to a designated transportation officer. The emergency plan should inventory and include the function of all available drivers and transportation equipment, such as buses, trucks, maintenance vehicles, and automobiles. Arrangements in advance also might be made to obtain additional vehicles from bus companies, leasing companies, or garages. Also, by prior agreement, the use of vehicles owned by airport employees can be included in the emergency plan. All plans for vehicle use should include qualified operators for the vehicles.

3-12.2

In airport emergencies, provision should be made for an easily identifiable guide vehicle(s), equipped with two-way radio communication, to lead groups of vehicles from the rendezvous point(s) or staging area to the accident site to avoid interference with aircraft operations.

3-12.3

The transportation officer in charge should wear a lime green hard hat and lime green vest or other apparel with distinctive reflective lettering that reads "TRANSPORTATION OFFICER" displayed back and front.

3-12.4

Suitable rescue equipment and services should be available for use at an airport where the area to be covered by the appropriate services includes water or swampy areas or other difficult terrain that cannot be fully served by conventional wheeled vehicles. This is particularly important where a significant portion of approach and departure operations take place over these areas.

3-13 Rescue Coordination Center.

Rescue coordination centers can play a significant role in an aircraft accident occurring in the vicinity of an airport if the site of the accident is not known or if rescue facilities in addition to those available at or near the airport are required to be brought into action. Rescue coordination centers should have means of immediate communication with all rescue units within their areas of responsibility, including units able to provide aircraft, helicopters, and special rescue teams and, where appropriate, with coastal radio stations capable of alerting and communicating with surface vessels. Assistance from these units can be essential in responding to an accident in the vicinity of the airport. It is therefore suggested that the potential role of the rescue coordination center be specifically highlighted in the proposed airport emergency plan document in a separate paragraph.

3-14 Civil Defense.

The airport emergency plan should be integrated with the local community civil defense emergency plan and with local search and rescue teams. Consideration should be given to the role the airport may have as a result of coordination with civil defense officials and in support of any civil defense emergency plan requirements.

3-15 Mutual Aid Agencies.

3-15.1*

Airport emergencies can be of such magnitude that local rescue and fire fighting, security, law enforcement, and medical services are inadequate to handle the situation. It is therefore strongly recommended that written mutual aid agreements be initiated to ensure the prompt and orderly response of these agencies.

3-15.2

All mutual aid agreements should be reviewed or revised annually. Telephone and personnel contacts should be reviewed and updated monthly.

3-16* Harbor Patrol and Coast Guard.

Harbor Patrol and Coast Guard services are vital to airports adjacent to large bodies of water. Coordination of such services should be included in the Plan where applicable. Communication requirements to obtain the immediate response of such services (and the ability to communicate during the emergency) should be an essential ingredient of the Plan.

If the area where the boats are to be operated is subject to freezing, vehicles suitable for operation on ice (i.e., hover craft, swamp boats, etc.) should be available.

3-17 Military.

Where a military installation is located on or in the vicinity of an airport, a mutual aid agreement should be initiated to integrate personnel with command, communication, and coordination functions of the emergency plan.

3-18 Clergy.

The Plan should include advance agreements with clergy of all faiths to provide comfort to casualties and relatives.

3-19 Public Information Officer.

A public information officer should be designated. This officer should coordinate and release factual information to the news media and also should coordinate public information statements between all parties involved.

It is recommended that the television and radio news media be requested to withhold the release of accident information to allow sufficient time for adequate security to be established. Past history has shown that, as knowledge of the accident spreads, onlookers flock to the site and interfere with emergency vehicles' access to the incident.

3-20 Mental Health Agencies.

The emergency plan should include the local mental health agencies. Therapeutic treatment as well as follow-up procedures for dealing with the possible long-term effects of the emergency should be available for survivors, relatives, eyewitnesses, and emergency scene personnel.

Chapter 4 Functions of Each Agency for an Aircraft Accident on the Airport

4-1 General.

The airport/community emergency plan should be implemented immediately upon an aircraft accident occurring on the airport. Responding agencies should comply with Sections 4-2 through 4-10.

4-2 Action by Air Traffic Control (ATC) Services.

4-2.1

Air traffic control services should initiate emergency response by using the alarm communications system. (*See Figure 4-2.1.*)

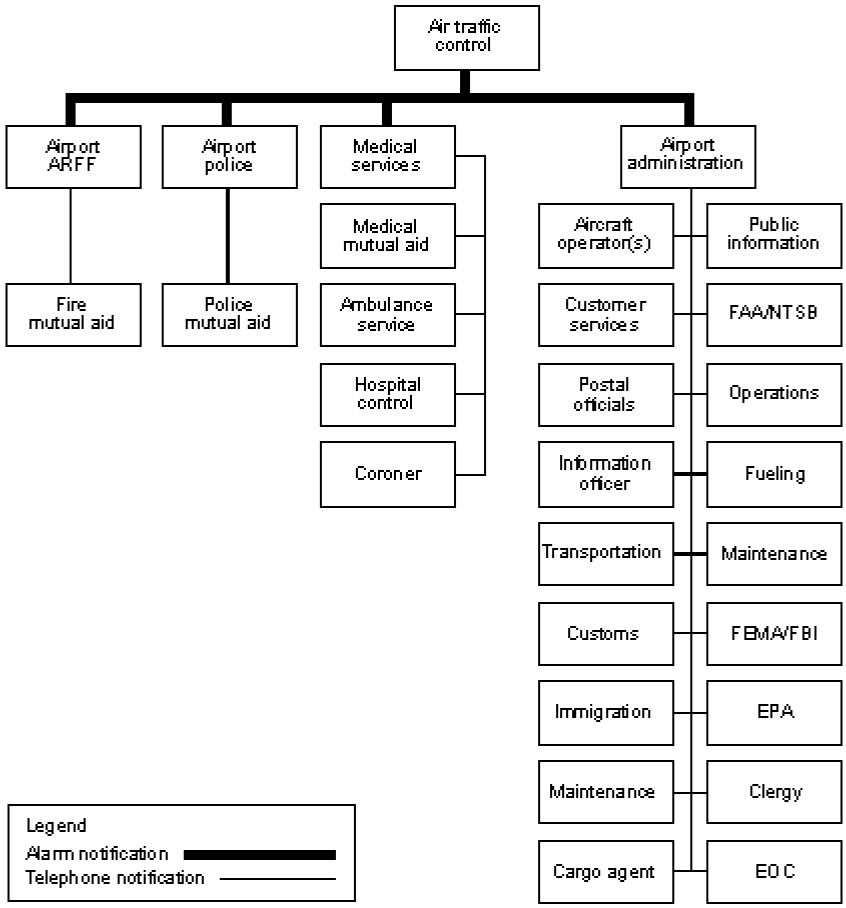


Figure 4-2.1 Sample notification chart — aircraft accident on airport.

4-2.2*

Information on the location of the accident and type of alarm, giving grid-map reference or other identifying terrain features should be immediately provided by air traffic control services. These details should include the type of aircraft.

Subsequent calls can expand this information by providing details on the number of occupants, fuel on board, aircraft operator, if appropriate, and any dangerous goods or hazardous materials on board, including quantity and location.

4-2.3

Air traffic control should restrict airport operations and minimize vehicle traffic on that runway to prevent disturbance of accident investigation evidence.

4-2.4

An appropriate Notice to Airmen (NOTAM) should be issued immediately by air traffic control services. For example:

> "Airport rescue and fire fighting service protection unavailable until (time) or until further notice. All equipment committed to an aircraft accident."

4-2.5

Air traffic control should confirm that the actions above were completed, by written or computer checklist, indicating notification time(s) and name of person completing action.

4-3 Action by Rescue and Fire Fighting (RFF) Services.

4-3.1

An alarm for an aircraft accident on the airport will normally be received from the air traffic control services. When, however, an alarm is received from any other source, or an accident is observed, or there is reason to consider that one is imminent, the airport rescue and fire fighting services should take action in the same manner as if the air traffic control services had originated the alarm. The air traffic control services should be informed by the responding fire fighting services as to the nature of the alarm, its location, and the response initiated.

4-3.2

Airport rescue and fire fighting services should:

(a) Proceed via established access routes to the incident as indicated by air traffic control services.

(b) Advise mutual aid fire departments while en route of:

1. Rendezvous point;
2. Staging area;
3. Manpower and equipment required for support if known;
4. Any other pertinent information.

(c) Immediately establish an on-scene command post.

4-3.3

Command authority at any accident site should be predetermined according to the jurisdictional responsibilities of the agencies involved and as designated in the airport/community emergency plan.

4-3.4

Prior agreement should be reached between the on-airport rescue and fire fighting service and the off-airport mutual aid fire departments as to who is best equipped to fight fires in aircraft hangars or other airport structures. Additionally, there should be prior agreement as to which agency will be in command when an accident involves an aircraft or an airport structure or both.

4-4 Action by Police/Security Services.

4-4.1

The first security/police officer to arrive should coordinate with the incident commander and, to the extent possible, immediately establish free traffic lanes on ingress and egress roads for emergency vehicles, initiate security responsibility, and request reinforcements as needed.

Traffic flow and site security should be the primary responsibility of police and security personnel. They should notify the appropriate communications center of the location of the accident and available means of access and egress. After consultation with the incident commander, they should initiate traffic control measures in order to aid responding emergency vehicles.

They should notify the airport security communications center or the incident commander (where appropriate) of the location of the accident, access, ingress, and egress roads available, and where responding security personnel should make initial response and recommendations for setting up roadblocks away from the accident site to aid responding emergency vehicles. Responding police vehicles should not proceed directly to the accident site (unless instructed by police communications center officer) to view the scene, but set up appropriate roadblocks at least two to three blocks away, as directed by the local security communications center. The local/police communication officer should set up appropriate roadblock locations as indicated on the local grid map to prevent road congestion.

4-4.2

Security personnel and police should handle traffic in the vicinity of the accident site, admit only authorized emergency personnel to the scene, keep unauthorized persons from the accident site, and be responsible for preservation of the accident scene.

4-4.3

All unnecessary traffic should be routed away from and around the accident site.

4-4.4

The emergency site should be cordoned off as soon as possible to exclude intruders, media, sightseers, onlookers, and souvenir hunters. Appropriate markings should be prominently displayed to advise all persons of possible hazards that can cause serious injury should they encroach on the area.

4-4.5

Communications between all security check points and the command post or emergency operations center or both should be established as soon as possible.

4-4.6

Identifying arm bands, site passes, or I.D. tags should be issued by the authority having jurisdiction and monitored by the security services.

4-4.7

Special security provisions should be instituted for the protection of the flight data and cockpit voice recorders, any mail involved, and any dangerous goods (hazardous materials) that may be present.

4-5 Action by Airport Authority.

4-5.1

The airport authority representative should respond to the accident site and, as needed, set up an easily identifiable mobile command post. The mobile command post should be adequately staffed by senior representatives able to make decisions involving the following types of operations:

(a) Airport;

(b) Security;

(c) Medical;

(d) Aircraft; and

(e) Aircraft recovery.

4-5.2

The airport authority should commence written check list procedures to verify that:

(a) The airport emergency operations center has been activated;

(b) Mutual aid police procedures have been initiated and secondary notification calls have been made;

(c) Medical and ambulance services have been alerted and their arrivals verified at the designated rendezvous point or staging area;

(d) Mutual aid fire departments have been notified and escort has been provided for their access to the accident site;

(e) The affected aircraft operator has been notified and information obtained on any dangerous goods or hazardous materials on board the aircraft, e.g., explosive substances, flammable gases and liquids, combustible solids, oxidizing substances, poisonous substances, radioactive materials, or corrosives;

(f) Liaison has been established with air traffic control services concerning the closure of airport areas, designation of emergency response corridors, and issuing of voice advisories and Notices to Airmen (NOTAM) advising of reduced airport rescue and fire fighting protection;

(g) Government aircraft accident investigation authorities, such as the National Transportation Safety Board (NTSB), have been notified (if military aircraft is involved the appropriate military organization should be notified);

(h) The meteorological department has been notified to make a special weather observation;

(i) Arrangements have been made for the affected runway to be surveyed immediately by the appropriate personnel to identify the location of crash debris and to ensure that the debris be secured pending release by investigating agencies;

(j) Airspace reservation coordination offices (Air Traffic Flow Control Office), if any, have been advised of reduced airport capabilities;

(k) Medical Examiner’s/Coroner’s Office has been notified to assist with fatalities if necessary; and

(l) Temporary morgue facilities have been identified and designated.

4-5.3

In conjunction with mutual aid police, the airport authority should:

(a) Designate rendezvous points and staging areas for the inner and outer perimeters;

(b) Assign security personnel at the staging area or rendezvous point or both to escort vehicles so as to ensure the orderly flow of emergency personnel to the accident site, particularly the provision of escort for ambulances responding to the rendezvous point and from the staging area; and

(c) Assign parking areas for escort vehicles and ambulances, giving consideration to the need for rapid deployment when dispatched.

4-5.4

The airport authority also should, to the extent possible, arrange to have available the following services as may be required:

(a) Portable emergency shelter for use by other than medical services;

(b) Lavatories;

(c) Drinking water;

(d) Ropes, barriers, etc.;

(e) Food service;

(f) Mobile or portable lighting;

(g) Portable heating system;

(h) Cones, stakes, flags, and signs;

(i) Machinery, heavy equipment, and extraction tools;

(j) Communications equipment such as megaphone, portable telephone, etc.; and

(k) Fuel removal equipment.

4-5.5

The airport authority should provide the initial briefing for their airport public information officer. They should then coordinate, where appropriate, with the public information officer of the aircraft operator involved to provide the following:

(a) Media releases for the various media officers from the agencies involved; and

(b) Briefings and statements that will be released to the media.

4-5.6

Upon concurrence of the chief fire officer, police/security chief, and the medical coordinator, the airport authority's incident commander should notify all participating mutual aid organizations of termination of the airport emergency. Note that this may not terminate all actions and responsibilities of participating agencies.

4-6 Action by Medical Services.

The medical coordinator should coordinate with the medical transportation officer and medical services to:

(a) Verify that mutual aid medical and ambulance services have been alerted and verify their subsequent arrival at the rendezvous point or staging area and that a medical communication network is established;

(b) Organize the necessary action for triage and treatment of the casualties and their eventual evacuation by appropriate means of transportation;

(c) Provide control and dispatch of the casualties to the appropriate hospitals by land, sea, or air;

(d) Maintain an accurate list of the casualties including their names and their destination for treatment;

(e) Coordinate, with the aircraft operator concerned, the transportation of the uninjured to the designated holding area;

(f) Arrange for the restocking of the medical supplies, if necessary; and

(g) Provide medical analysis of the walking wounded or traumatized.

4-7 Action by Hospitals.

Hospitals listed in the emergency plan should be prepared to:

(a) Provide medical care to the casualties when they arrive;

(b) Provide doctors and trauma teams in accordance with the airport/community emergency plan; and

(c) Ensure that adequate doctors and nurses, blood, operating rooms, intensive care, and surgical teams are available for emergency disaster situations, including aircraft accidents.

4-8 Action by Aircraft Operators.

4-8.1

A senior aircraft operator representative should report to the command post to coordinate the aircraft operator activities with the incident commander.

4-8.2

The senior aircraft operator representative should provide information regarding passenger load, flight crew complement, and dangerous goods or hazardous materials on the aircraft. These include explosive substances, flammable liquids or gases, combustible solids, oxidizing substances, poisonous substances, radioactive materials, and corrosives. Information of this nature should be relayed as soon as possible to the chief fire officer and the medical coordinator.

4-8.3

The senior aircraft operator representative should make arrangements for bus transportation from the accident site to the designated traumatized holding area. Transportation of the walking wounded from the scene should be permitted only after consultation with the medical coordinator. Passengers should be under medical supervision while awaiting transportation, during transport, and at the receiving processing site.

4-8.4

The aircraft operator staff should proceed to the designated uninjured holding area. The senior aircraft operator representative at the uninjured holding area should appoint a receptionist, registrars, and welfare coordinators from staff who have been previously trained in these functions.

4-8.5

The aircraft operator representative who is in command of the uninjured holding area should oversee the overall operations by making arrangements for commissary items, clothing, telephone facilities, and additional medical services if required.

4-8.6

The receptionist should meet the buses as they arrive from the scene of the accident and direct the passengers to the registrars' tables where they will be processed. The receptionist also should explain where toilet facilities, telephones, and other amenities are located. However, migration outside the holding area should be prevented until each person transported to the holding area is identified and processed according to the Plan.

4-8.7

The registrar should record the passenger's name on the manifest and determine what reservation requirements are desired, i.e., hotel accommodation, air transportation, or other modes of transportation, etc., and any persons to be notified of the passenger's physical or mental condition and potential plans. The registrar then should make out an identification tag or sticker and place it on the passenger. When their registration is completed, the registrars then should direct passengers to the welfare coordinators.

4-8.8

Welfare coordinators and mental health specialists trained in stress management should:

(a) Give support and comfort to relatives and friends of persons on board the aircraft involved;

(b) Register relatives and friends waiting at the airport for information about persons on board;

(c) Provide care, comfort, and assistance to the walking injured and uninjured survivors and responding personnel (if required); and

(d) Assist in the provision and serving of refreshments to waiting relatives and friends.

The welfare plan should provide for a suitable location to carry out the functions as well as procedures for alerting and coordinating welfare organizations.

4-8.9

The aircraft operator should provide notification of the aircraft accident to:

(a) Health and welfare agencies;

(b) Customs, where applicable;

(c) Immigration, where applicable;

(d) Post office; and

(e) Environmental protection agencies if a fuel spill, fire-fighting actions, or airborne matter can affect the environment.

4-8.10

A senior aircraft operator official should arrange for the initial notification of relatives and friends.

4-8.11

News releases by aircraft operators should be prepared in conjunction with the airport public information officer and liaison officers from other agencies involved in the accident.

4-8.12

The aircraft operator is responsible for the removal of the wrecked or disabled aircraft as soon as authorized by the National Transportation Safety Board or their designee. For aircraft removal technique see, *International Civil Aviation Organization Airport Services Manual*, Part 5, "Removal of Disabled Aircraft." Also see *International Air Transport Association — Guidelines for Airport Operators and Airport Authorities on Procedures for Removal of Disabled Aircraft*.

4-9 Action by Government Authorities. The following government authorities can be required to take appropriate action as indicated in their emergency plan:

(a) National Transportation Safety Board;

(b) Federal Aviation Administration;

(c) Health and welfare;

(d) Post office;

(e) Customs;

(f) Immigration;

(g) Agriculture; and

(h) Public works.

4-10 Action by the Public Information Officer.

4-10.1

All media personnel should be directed to a designated news media staging area for news media personnel authorized to cover an airport emergency. At this area the following should be provided:

(a) Latest briefing;

(b) Communications (telephones); and

(c) Transportation service to and from the scene of the emergency, where permissible and where it will not interfere with rescue, medical treatment of casualties, and the accident investigation.

4-10.2

Only members of the news media, freelance reporters, and photographers wearing a valid regular police working news media card should be admitted to the briefing area or permitted in the designated news media staging area or transported to the scene of the emergency.

4-10.3

In general, the official authority for news releases concerning an aircraft emergency should be that of:

(a) A public information officer designated by the airport authority; or

(b) The representative of the aircraft operator involved; or

(c) Both.

4-10.4

Under no circumstances should the news media or any other personnel not involved in life saving or fire fighting operations be permitted inside security lines until all rescue operations have been completed and the area has been declared safe by the chief fire officer. When establishing security lines, the interests of news coverage should be taken into account in so far as rescue operations permit.

4-11 Organization Charts.

4-11.1

Organization charts should be prepared for each anticipated type of emergency situation, off-airport incident, on-airport incident, earthquake, or flood.

4-11.2

These charts should depict the relationships and duties of all components of the Plan in such detail that each participating agency has a full understanding of its duties and responsibilities.

Chapter 5 Functions of Each Agency for an Aircraft Accident off the Airport

5-1 General.

The airport/community emergency plan should be implemented immediately upon an aircraft accident occurring off the airport. Responding agencies should comply with Sections 5-2 through 5-10.

5-2 Action by Air Traffic Control (ATC) Services.

5-2.1

Air traffic control services should initiate emergency response by using the alarm communications system. (*See Figure 5-2.1.*)

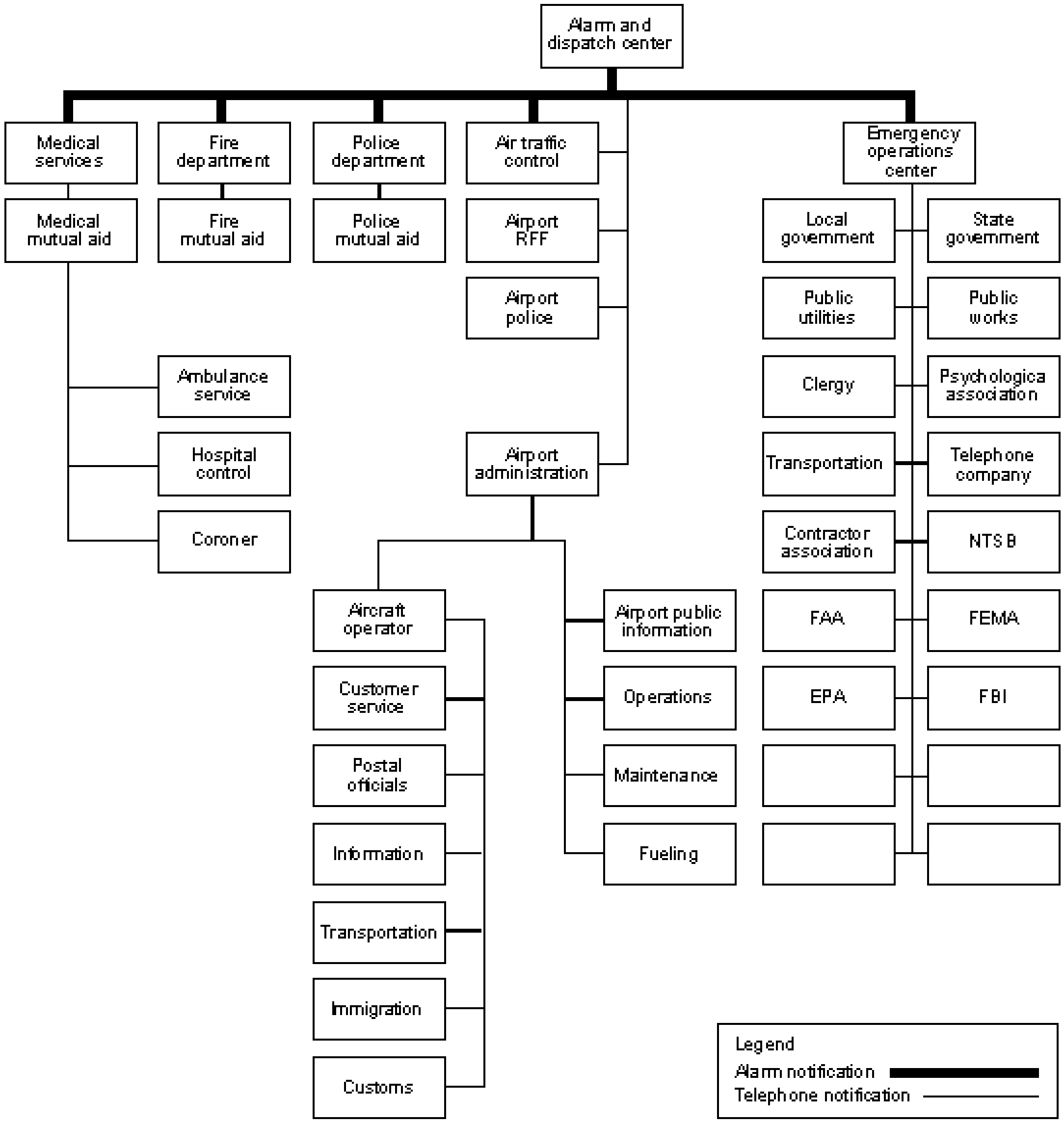


Figure 5-2.1 Sample notification chart — aircraft accident off airport.

5-2.2*

Information on the location of the accident and type of alarm, giving grid-map reference or other identifying terrain features, should be provided immediately by air traffic control services.

Subsequent calls can expand this information by providing details on the number of occupants, fuel on board, aircraft operator, if appropriate, and any dangerous goods or hazardous materials on board, including quantity and location.

5-2.3

Air traffic control should alert the airport rescue and fire fighting service, police and security services, airport authority, and medical services in accordance with the procedure in the airport/community emergency plan, giving grid-map reference.

5-2.4

If requested by the fire department having jurisdiction over the accident area, air traffic control should provide for dispatch of the RFF service in accordance with the Plan and any mutual aid agreements.

An appropriate Notice to Airmen (NOTAM) should be issued immediately. For example:

> "Airport rescue and fire fighting service protection unavailable until (time) or until further notice. All equipment committed to an aircraft accident."

5-2.5

Air traffic control should confirm that the actions above were completed, by written or computer checklist, indicating notification time(s) and name of person completing the action.

5-3 Action by Rescue and Fire Fighting (RFF) Services.

5-3.1

A call for an aircraft accident off the airport normally is received from the air traffic control services, local police, or local fire departments. Designated vehicles should be sent in accordance with the existing mutual aid department agreements.

5-3.2

Responding airport rescue and fire fighting services should:

(a) Proceed via preestablished access routes, considering vehicle weight, height, and width, to the off-airport accident site in coordination with local police/security direction.

(b) While en route, advise or request of fire department having jurisdiction over the area:

1. Rendezvous point or staging area or both;
2. Staffing and equipment responding; and
3. Any other pertinent information.

5-3.3

The senior airport fire officer should report to the senior fire officer of the fire department having jurisdiction over the area and request orders.

5-3.4

Prior agreement should be achieved between the on-airport rescue and fire fighting service and the local fire department in command and mutual aid fire departments as to who is best equipped to fight fires involving aircraft or structures or both. Additionally, there should be prior agreement as to which agency will act in command when an accident involves both an aircraft and an off-airport structure.

5-4 Action by Police/Security Services.

5-4.1

The first security/police officer to arrive should coordinate with the incident commander and, to the extent possible, immediately establish free traffic lanes on ingress and egress roads for emergency vehicles, initiate security responsibility, and request reinforcements as needed.

Traffic flow and site security are the primary responsibility of police and security personnel. They should notify the appropriate communications center of the location of the accident and available means of access and egress. After consultation with the incident commander, they should initiate traffic control measures in order to aid responding emergency vehicles.

5-4.2*

Security personnel and police will be needed to handle traffic in the vicinity of the accident site and to prevent disturbance of material scattered over the accident site.

The emergency site should be cordoned off as soon as possible to exclude intruders, media, sightseers, onlookers, and souvenir hunters. Appropriate markings should be prominently displayed to advise all persons of possible hazards that can cause serious injury should they encroach on the area. Flares should not be used within 300 ft (100 m) of the accident site to prevent ignition of fuel vapors.

5-4.3

Communications between all security checkpoints and the command post or emergency operations center or both should be implemented as soon as possible.

5-4.4

Identifying arm bands, site passes, or I.D. tags should be issued by the controlling authority and monitored by the security/police officer and his or her team.

5-4.5

Special security provisions should be made to protect the flight data and cockpit voice recorders, any mail involved, or dangerous goods or hazardous materials that might be present.

5-5 Action by Emergency Medical Services.

The medical coordinator should coordinate with the medical transportation officer and medical services to:

(a) Verify that mutual aid medical and ambulance services have been alerted and verify their subsequent arrival at the rendezvous point or staging area and that a medical communication network is established;

(b) Organize the necessary action for triage and treatment of the casualties and their eventual evacuation by appropriate means of transportation;

(c) Provide control and dispatch of the casualties to the appropriate hospitals by land, sea, or air;

(d) Maintain an accurate list of the casualties including their names and their destination for treatment;

(e) Coordinate, with the aircraft operator concerned, the transportation of the uninjured to the designated holding area;

(f) Arrange for the restocking of the medical supplies, if necessary; and

(g) Provide medical analysis of the walking wounded and uninjured.

5-6 Action by Hospitals.

Hospitals listed in the emergency plan should be prepared to:

(a) Ensure that adequate doctors and nurses, and operating room, intensive care, and surgical teams are available for emergency situations, including aircraft accidents;

(b) Provide medical care to the casualties when they arrive;

(c) Provide doctors and trauma teams to the accident site in accordance with the Plan; and

(d) Notify coroner/medical examiner.

5-7 Action by Airport Authority.

If previously agreed on in the airport mutual aid emergency agreement with the surrounding community, the following actions can be taken by the airport authority:

(a) Report to the accident site;

(b) Ensure that, if required, the airport emergency operations center and the mobile command post are activated;

(c) Extend as much emergency aid as requested by the jurisdiction agency in command of the off-airport accident/incident;

(d) Notify the aircraft operator involved; and

(e) Notify other agencies as required.

According to the mutual aid emergency agreement with the surrounding community, the airport authority can provide, if requested and if available, a part of its medical equipment (i.e., first aid equipment, stretchers, body bags, mobile shelters, etc.) and the assistance at the accident site of doctors and personnel teams qualified in emergency first aid.

5-8 Action by Aircraft Operators.

5-8.1

A senior aircraft operator representative should report to the command post to coordinate with the incident commander.

5-8.2

The senior aircraft operator representative should provide information regarding passenger load, flight crew complement, and dangerous goods or hazardous materials on the aircraft. These include explosive substances, gases, flammable liquids or solids, oxidizing substances, poisonous substances, radioactive materials, and corrosives. Information of this nature should be relayed as soon as possible to the chief fire officer and the medical coordinator.

5-8.3

The senior aircraft operator representative should make arrangements for bus transportation from the accident site to the designated uninjured holding area. Transportation of the walking wounded from the scene should be permitted only after consultation with the medical coordinator.

5-8.4

The aircraft operator staff should proceed to the designated uninjured holding area. The senior aircraft operator representative at the uninjured holding area should appoint a receptionist, registrars, and welfare coordinators from staff who have been previously trained in these functions.

5-8.5

The aircraft operator representative who is in command of the uninjured holding area should oversee the overall operations by making arrangements for commissary items, clothing, telephone facilities, and additional medical services if required.

5-8.6

The receptionist should meet the buses as they arrive from the scene of the accident and direct the passengers to the registrars' tables where they will be processed. The receptionist should know where support facilities such as toilet facilities, telephones, clothing, and drinking water are located.

5-8.7

The registrar should record the passenger's name on the manifest and determine what reservation requirements are desired, i.e., hotel accommodation, air transportation, or other modes of transportation, etc., and names of any persons to be notified of the passenger's physical or mental condition and potential plans. The registrar should make out an identification tag or sticker (available from the emergency kit) and place it on the passenger. When their registration is completed, the registrars then should direct the passengers to the welfare coordinators.

5-8.8

Where necessary, the aircraft operator should provide notification of the aircraft accident to:

(a) Health and welfare agencies;

(b) Customs, where applicable;

(c) Immigration, where applicable;

(d) Post office;

(e) Agriculture agencies;

(f) Environmental Protection Agency (EPA); and

(g) National investigative agency NTSB (FBI).

5-8.9

A senior aircraft operator official should be responsible for the initial notification of relatives and friends.

5-8.10

News releases by aircraft operators should be prepared in conjunction with the airport public information officer and liaison officers from other agencies involved in the accident.

5-8.11*

The aircraft operator is responsible for the removal of the wrecked or disabled aircraft, as soon as authorized by the aircraft accident investigation authority.

5-9 Action by Government Authorities.

The following government authorities, after being notified, can be required to take appropriate action as indicated in their emergency plan:

(a) Government accident investigation personnel;

(b) Health and welfare;

(c) Post office;

(d) Customs;

(e) Immigration; and

(f) Agriculture.

5-10 Action by the Public Information Officer.

5-10.1

The responsibility for news releases concerning an off-airport emergency should be that of:

(a) The representative of the aircraft operator;

(b) A public information officer designated by the service government authority in command; and

(c) A public information representative designated by the airport authority.

5-10.2

Under no circumstances should the media or other personnel not directly involved in the fire fighting, rescue, or emergency medical care be permitted inside security lines until all rescue operations have been completed and the area is declared safe for entry by the incident commander/chief fire officer.

Chapter 6 In-Flight Emergencies

6-1 Full Emergency Incident — Aircraft in Flight.

6-1.1

The agencies involved in the airport/community emergency plan should be alerted to “full emergency” status when it is known that an aircraft approaching the airport is, or is suspected to be, in such trouble that there is a strong likelihood of an accident.

6-1.2 Action by Air Traffic Control Services.

6-1.2.1 Air traffic control services should call the airport rescue and fire fighting service to stand by at the predetermined standby positions applicable to the runway to be used and provide as many of the following details as possible:

(a) Type of aircraft;

(b) Nature of trouble;

(c) Runway to be used;

(d) Estimated time of landing;

(e) Aircraft operator, if appropriate;

(f) Fuel on board;

(g) Number of occupants, including special occupants — handicapped, immobilized, blind, deaf, etc.; and

(h) Any dangerous goods or hazardous materials on board, including quantity and location, if known.

6-1.2.2 The calling of the mutual aid fire department(s) and other appropriate organizations should be initiated by air traffic control services in accordance with the procedure laid down in the airport/community emergency plan, giving, where necessary, rendezvous point and airport entrance to be used.

6-1.3 Action by Other Agencies.

The specific responsibilities and roles of the various agencies itemized in Sections 4-2 to 4-10 for responding to an aircraft accident on the airport can be applied for "full emergency" as required by local operating requirements.

6-2 Local Standby.

6-2.1

The agencies involved in the airport/community emergency plan should be alerted to "local standby" status when an aircraft approaching the airport is known or is suspected to have developed some defect, but the trouble is not such that would normally involve any serious difficulty in effecting a safe landing.

6-2.2 Action by Air Traffic Control Services.

6-2.2.1 Air traffic control should call the airport rescue and fire fighting service to stand by as requested by the pilot or to stand by as local airport agreements require at the predetermined standby positions applicable to the runway to be used. As many of the following details as possible should be provided:

(a) Type of aircraft;

(b) Nature of trouble;

(c) Runway to be used;

(d) Estimated time of landing;

(e) Fuel on board;

(f) Number of occupants, including special occupants — handicapped, immobilized, blind, deaf, etc.;

(g) Aircraft operator, if appropriate; and

(h) Any dangerous goods or hazardous materials on board, including quantity and location, if known.

6-2.2.2 Action by Other Agencies. The specific responsibilities and roles of the various agencies itemized in Sections 4-2 through 4-10 for responding to an aircraft accident on the airport can be applied for "local standby" as required by local operating requirements.

Chapter 7 Other Emergencies

7-1 General.

Procedures and techniques used in handling nonaircraft accident related airport emergencies should be similar to the techniques used in handling aircraft accident emergencies. It should be recognized that medical and fire emergencies can arise at any location where large numbers of persons work or congregate. At airports this problem can be severe because of the exposure associated with the commonplace activities of arriving and departing passengers and sightseers, the public service facilities provided at airports (i.e., automobile movement and parking areas, restaurants, bars, baggage handling and storage areas, etc.), and the fact that airports can be selected by malcontents as locations to demonstrate their anger against any group or activity.

7-1.1

The diverse character of persons traveling by air suggests the need for the airport authority to arrange to have available emergency medical services to treat conditions such as cardiac arrest, abdominal pains, burns, cuts, abrasions, and other medical problems. This can require immediate care facilities and detailed mutual aid plans with outside agencies.

7-1.2

The natural disasters airports can be subjected to include storms, floods, earthquakes, and seismic sea waves. The vulnerability of an airport to any of these will, in good measure, be affected by geography. While nothing can be done to avert them, there are actions that can be taken to minimize damage and expedite restoration of aircraft operations.

7-1.3

Development of weather patterns, prediction and tracking of storm movement, and notification to the public of potential danger resulting therefrom will normally be carried out by a meteorological service in the area.

7-1.4

The airport/community emergency plan should provide for initial protective measures, personnel shelter, and post-storm cleanup and restoration. Aircraft operations might be impossible for several hours before the arrival of the storm and until several hours after its passing.

7-1.5

As soon as severe storm warnings are received, all owners of aircraft based or on the ground at the airport should be notified and warnings issued to all aircraft pilots en route to the airport. Aircraft owners and pilots should be responsible for their aircraft but, if possible, all aircraft on the ground should be evacuated to airports outside the storm area. Aircraft in flight should be advised to divert to an alternative destination. Aircraft on the ground that cannot be dispersed should be put under cover or tied down so as to face into the approaching winds.

7-1.6

Power interruptions are common during a natural disaster, either by damage to generating plants or by destruction of transmission lines. Airports located in severe storm areas should take measures to ensure minimum interruption to power supply, either by providing standby electrical generators or dual sources of commercial power for essential functions.

7-1.7

Regarding building protection, specific personnel assignments should be made in the airport/community emergency plan to collect or secure all loose objects that can be blown about by the winds and to fill and place sandbags if there is any possibility that the storm is accompanied by floods.

7-1.8

Where the Aircraft Rescue and Fire Fighting (ARFF) provides a commitment to assist in non-aircraft-related emergencies, attendance at those incidents should not compromise their immediate agreed upon level of response to aircraft accidents or incidents.

7-2 Sample Notification Charts.

7-2.1

The examples illustrated in Figures 4-2.1 and 5-2.1 can assist in rapid communication in the event of an emergency. Accordingly, they should contain all the vital telephone numbers.

7-2.2

Separate sample notification charts should be developed for each type of emergency included in the Plan. It is important that the method of notification be clearly outlined in the airport/community emergency plan.

7-2.3

Telephone numbers should be verified monthly and a revised list issued if necessary. In order to require only one page to be reissued when a change occurs, each sample notification chart should be printed on one sheet.

Chapter 8 Emergency Operations Center and Mobile Command Post

8-1 General.

The emergency operations center is a fixed designated area on the airport that is usually used in supporting and coordinating operations in accidents/incidents, unlawful seizure of aircraft, and bomb threat incidents. The unit should have the necessary communication equipment and personnel to communicate with the appropriate agencies involved in the emergency, including the mobile command post, where this is deployed. The communication and electronic devices should be checked daily.

8-2 Emergency Operations Center.

8-2.1

An emergency operations center should be available for the purpose of dealing with emergency situations at each airport.

8-2.2

The emergency operations center should provide:

(a) A fixed location;

(b) Support of the incident commander in the mobile command post for aircraft accidents/incidents;

(c) A command, coordination, and communication center for unlawful seizure of aircraft and bomb threats; and

(d) Operational availability 24 hours a day.

8-2.3

The location of the emergency operations center should provide a clear view of the movement area and isolated aircraft parking position, wherever possible.

8-3 Mobile Command Post.

(*See Figure 8-3*.)Figure 8-3

Figure 8-3 Mobile command post.

8-3.1

Certain emergency situations also will require a mobile command post at the scene. This mobile unit is normally provided by the airport authority and, during the emergency, is normally under the direction of the incident commander.

8-3.2

The mobile command post is a point where cooperating agency heads assemble to receive and disseminate information and make decisions pertinent to the rescue operations. The main features of this unit are:

(a) It is a mobile facility capable of being rapidly deployed;

(b) It serves as command, coordination, and communications center for aircraft accidents or incidents; and

(c) It is operational during aircraft accidents or incidents.

8-3.3

In the event of any accident or incident, a designated, recognizable, and highly visible mobile command post should be a high-priority item. It should be established as quickly as possible and preferably with the initiation of fire control and rescue activities. It is important that a continuity of command be maintained so that each agency reporting to the mobile command post can be adequately briefed on the situation before proceeding to assume control of its individual responsibilities.

8-3.4

The mobile command post unit should contain the necessary communications equipment and personnel to communicate with all agencies involved in the emergency, including the emergency operations center. The communication and electronic devices should be checked monthly or periodically as required by local conditions.

8-3.5

Maps, charts, and other relevant equipment and information should be immediately available at the mobile command post.

8-3.6

The mobile command post should be easily recognizable by provision of an elevated distinguishing marker, such as a checkered flag, colored traffic cone, balloon, or rotating light.

8-3.7

In some cases it might be necessary to establish a subcommand post. Where this is required, one location should be designated as a “master” command post with adequate communications to the subcommand post.

Chapter 9 Communications

9-1 Communications Network.

9-1.1

A coordinated communications network should be a prerequisite to any large-scale operation that involves agencies from more than one jurisdiction.

9-1.2

A communications network should consist of a sufficient number of radio transceivers, telephones (both mobile and land line), and other communication devices to establish and maintain a primary and a secondary means of communication. These networks should link the emergency operations center and the command post with each other as well as with all participating agencies. (*See Figure 10-2.*)

9-1.3

The operational communications network should provide a primary and, where necessary, an alternate, effective means for direct communications between the following, as applicable:

(a) The alerting authority (control tower or flight service station, airport manager, fixed-base operator, or airline office) and the RFF units serving the airport;

(b) Air traffic control tower or flight service station or both, the appropriate fire department alarm room/dispatch center(s), and the fire fighting and rescue and medical services personnel en route to an aircraft emergency and at the accident/incident site;

(c) Appropriate mutual aid agencies located on or off the airport, including an alert procedure for all auxiliary personnel expected to respond; and

(d) The RFF vehicles including a communications capability between crew members on each RFF vehicle.

9-2 Communications Equipment.

9-2.1

It is important to provide serviceable communications equipment in sufficient quantity to ensure rapid response of personnel and equipment to an emergency. The following communications equipment should be available for immediate use in the event of an emergency.

9-2.2 Portable Radios.

A sufficient number of portable, two-way radios should be available to provide each participating agency with the ability to communicate with the command post.

9-2.3

Strict communication discipline should be employed to prevent jamming of emergency frequencies. Each agency should operate on its own frequency, and there should be a designated command frequency.

9-2.4

Radios should be available at the command post to provide direct communication with the aircraft or ground controllers should it become necessary.

Direct communications also can be established between the pilot or the aircraft cockpit by use of cockpit-to-ground lines. This requires a proper connector, wire, microphone, and headset. Cooperation and coordination between the airport fire and rescue service and the individual air carrier(s) are needed to establish this type of communication capability. Normally this communication capability results from the use of a ground service headset that is plugged into a wheelwell interphone jack.

9-2.5

A sufficient number of telephone lines (both listed and unlisted) or cellular phones should be available at the command post to provide direct communication with agencies outside the airport, as well as within the airport. Direct lines save time and reduce the probability of overwhelming radio communication channels.

9-2.6

Medical facilities and ambulances need communications capability in order to take advantage of advance life support systems within the medical community.

9-2.7

A dedicated vehicle equipped with necessary communications equipment and self-contained electrical power is a definite asset to a good communication system. A well-equipped communications vehicle is an indispensable part of an efficient, well-managed command post. Planning should always include a qualified vehicle driver/operator.

9-2.8

Recording devices, with time insertion units, should be installed at the operations center or mobile command post or both to ensure that all communications are recorded for later analysis. All emergency communications, including printed communication, should be recorded.

9-2.9

Runners should be assigned to the command post to augment other modes of communication. Their use can prove invaluable should a temporary lapse of communication occur.

9-3 Testing and Verification.

9-3.1

The communications system should be tested daily to verify the operability of all radio and telephone networks.

9-3.2

A complete and current list of interagency telephone numbers should be available to all agencies and to personnel responsible for the airport/community emergency plan. These phone numbers should be verified monthly to ensure that they are correct.

Chapter 10 Command and Coordination for Airport/Community Emergency Plan

10-1 General.

10-1.1

Once an accident has occurred on the airport, the direction and control of rescue and fire fighting operations should be the responsibility of the airport rescue and fire fighting service officer in charge. Any transition of authority and command responsibility should be established previously in the emergency plan and exercised accordingly. Off-airport accidents should be under the direction and control of the jurisdiction where the accident occurred.

10-1.2

The Plan should be very specific in its designation of other responsible entities and their authority and function in the command organization.

10-2 Incident Command System.

The Plan should include a flexible organization system that enhances management of all activities at the accident site. This system should include a description of each element of the Plan, the agency assigned to the specific element, and a brief summary of the authority and responsibility necessary to execute the element. A diagrammatic representation of an organization chart from a typical incident command system is shown in Figure 10-2.

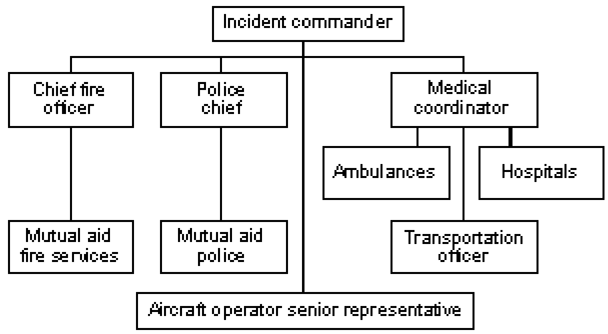


Figure 10-2 Command flow diagram.

Chapter 11 Emergency Medical Care

11-1 Basis of Recommendations.

11-1.1*

These recommendations are based upon the existence of an established level of emergency medical service that can be expanded into a comprehensive emergency medical system at the scene of an aircraft accident with numerous casualties.

11-1.2

Responsibilities of the emergency medical organization should include all aspects of medical care at the scene of an aircraft accident: triage, treatment, and transportation.

11-2 Emergency Medical Training of Airport Personnel.

11-2.1*

All airport fire department personnel assigned to fire control and rescue duties and all public contract airport employees ideally should be given first aid and CPR training. At least two full-time members of the airport fire department per shift should be trained to an EMT level and should be available to respond to any airport emergency of any severity.

11-2.2

The following subjects are the minimum that should be covered in a course of instruction to enable airport personnel to function effectively in providing emergency medical services:

(a) Airway management and cardiopulmonary resuscitation (CPR);

(b) Control of bleeding;

(c) Fractures and splinting with emphasis on spinal injuries;

(d) Burns;

(e) Shock;

(f) Emergency childbirth and immediate care of newborns, including prematures;

(g) Common medical diseases that can influence the outcome of injury (allergies, high blood pressure, diabetes, pacemaker, etc.);

(h) Basic measures for treatment and protection subsequent to spills or leaks of radioactive materials or toxic or poisonous substances;

(i) Basic measures for handling emotionally disturbed persons;

(j) Recognition and first aid for poisons, bites, and anaphylactic shock;

(k) Transportation techniques for injured persons;

(l) Heimlich maneuver—treatment of choking victims; and

(m) Protection against the spread of communicable diseases.

11-3 Airport Emergency Medical Supplies and Equipment.

11-3.1

Sufficient medical supplies to treat the capacity of the largest aircraft normally utilizing the airport should be available on or adjacent to the airport. Adequate supplies should be kept on hand to deal with routine medical emergencies (i.e., on-the-job injuries, cardiac arrest, etc.).

11-3.2

The type and quantity of such supplies should be determined by the principal medical authority for the airport.

Recent incidents have demonstrated that the unique characteristics presented by any given location should be taken into consideration when deciding on the type and quantity of supplies to be kept available for major incidents. For instance, extremes in temperatures should be considered and appropriate supplies stockpiled. Geographical conditions or topographical conditions or both also should be taken into consideration. The type and quantity of all medical supplies stockpiled should be determined by the agency responsible for providing emergency medical service to the airport.

11-3.3

Stretchers, blankets, cervical collars, backboards, and body bags should be located on the airport, preferably on a suitable vehicle (e.g., trailer) that can be transported to the accident site. Blankets are needed to alleviate the victims' exposure to shock and possible adverse weather conditions. The backboards and spine boards should be of a type designed to fit through access ways and aisles of commercial and business aircraft. They should have restraining straps available so the patient can be secured to the board. A cleat should be attached to the underside of the backboard to facilitate lifting by carrying personnel.

11-3.4

Sufficient resuscitation equipment should be available to treat smoke inhalation victims. This equipment should not be used around fuel or fuel soaked clothing.

11-4 Airport Medical Service.

11-4.1

Emergency medical service should be readily available to an airport. Minimum considerations for level of service should include:

(a) Number of passengers served;

(b) Number of persons employed at the airport;

(c) Industrial activity on airport property; and

(d) Distance from adequate medical facilities.

Ideally, each airport should have a properly staffed and equipped first aid room/medical facility on site and in addition should arrange for the emergency response of trained medical personnel with the capability to treat serious injuries and transport them to proper medical facilities.

11-4.2

The primary purpose of emergency medical services is to provide triage, treatment, and transportation in order to stabilize, provide comfort, and transport victims/patients to appropriate medical facilities.

11-4.3

The delivery to the accident site of trained medical personnel capable of treating and transporting injured victims of an aircraft accident is a vital component of the airport community emergency plan. The Plan should determine who will provide this service and should make all necessary legal and financial arrangements before the accident occurs. This includes integration with local community plans or mutual aid agreements or both.

11-4.4

Medical and ambulance services can be an integral part of the airport services, particularly the ambulance service that is, in many cases, part of the airport rescue and fire fighting service. If medical and ambulance services are not available at the airport, prearrangements with local agencies providing these services should be made. The Plan should ensure the dispatch of a satisfactory assignment of trauma-trained emergency service medical personnel, equipment, and medical supplies. The Plan should address the location of surrounding medical facilities and the level of service each provides.

11-4.5

The Plan should provide for the control of patient transport from the scene to the receiving medical facilities. The Plan’s incident command system should include a transportation control officer. This position’s responsibilities should include:

(a) Communications with medical facilities or the central communications point or both for local medical facilities;

(b) Overseeing and ensuring effective priority casualty transportation to the appropriate medical facilities; and

(c) All other aspects of medical transportation.

This has proven to be a very demanding and labor intensive responsibility, requiring a minimum of three subordinate positions. They are:

(a) Transportation control (routing of ambulances to and from the scene);

(b) Transportation recorder (responsible for documentation of all patient movement); and

(c) Medical communications (responsible for all communications regarding medical transportation).

A fourth position, that of ambulance staging leader, also should be considered.

11-4.6

Participating hospitals should have contingency emergency plans to provide for mobilization of necessary medical teams to the accident site in the shortest possible time. Availability of qualified personnel and adequate facilities at the hospitals to deal with airport emergency situations is vital. In this respect, it should be mandatory to establish in advance an accurate list of surrounding hospitals classified according to their effective receiving capacity and specialized features such as neurosurgical ability, burn treatment, etc.

11-4.7

The distance from the airport and the ability to receive helicopters should be considered. Reliable two-way communications should be provided between hospitals, and ambulances and helicopters. The alert of an aircraft accident should be made to a single communication controlling medical facility, which then alerts all other facilities according to the local medical communications network. Prior provision for police escort vehicles and helicopters for medical staff should be arranged in the Plan.

11-5 Airports without a Medical Care Facility.

At airports where a medical care facility (medical clinic or first aid room) is not available, the airport authority should make arrangements to have available sufficient personnel trained in advanced first aid to cover all active hours of airport operation. Equipment for first aid work at these airports should consist, at minimum, of an emergency medical care bag. This bag should be readily available to be carried on a designated airport emergency vehicle and should contain at least:

(a) One plastic sheet 1.80 m × 1.80 m (6 ft × 6 ft), with four spikes;

(b) Seven hemostats (one package of three, one package of four);

(c) Two field dressings one 450 mm × 560 mm (18 in. × 22 in.), one 560 mm × 910 mm (22 in. × 36 in.);

(d) Ten abdominal pads (five packages of two);

(e) Forty 100 mm × 100 mm (4 in. × 4 in.) gauze pads (four packages of ten);

(f) Two tourniquets;

(g) One artificial airway;

(h) Three disposable airways (each with No. 2, No. 4, No. 5);

(i) One bulb syringe with two catheters (No. 12, No. 14 FR);

(j) Two large bandage scissors;

(k) Twenty disposable syringes with No. 25 GA 16-mm (.6-in.) needle;

(l) Twelve ace bandages two 150 mm (6 in.), four 75 mm (3 in.), six 50 mm (2 in.);

(m) Twelve alcohol sponge packages;

(n) Four rolls of gauze bandage two 75 mm (3 in.), two 50 mm (2 in.);

(o) Two rolls of adhesive tape;

(p) Four Vaseline gauze dressings 150 mm × 910 mm (6 in. × 36 in.);

(q) One box of 100 bandaids, assorted sizes;

(r) One blood pressure cuff and gauge;

(s) Two clipboards 220 mm × 280 mm (8 in. × 11 in.);

(t) Six pencils (pens, grease pencils, etc.);

(u) Sufficient supply of casualty identification tags (*see A-11-6.7*);

(v) One set of inflatable splints;

(w) One resuscitube;

(x) One short spine board;

(y) One flashlight;

(z) Two cervical collars;

(aa) One bite-stick wedge;

(bb) One disposable obstetric kit; and

(cc) A sufficient supply of infection control equipment, including medical gloves, masks, protective eyewear, and gowns/aprons.

11-6 Immediate Need for Care of Injured in Aircraft Accidents.

(*See Figure 11-6.*)

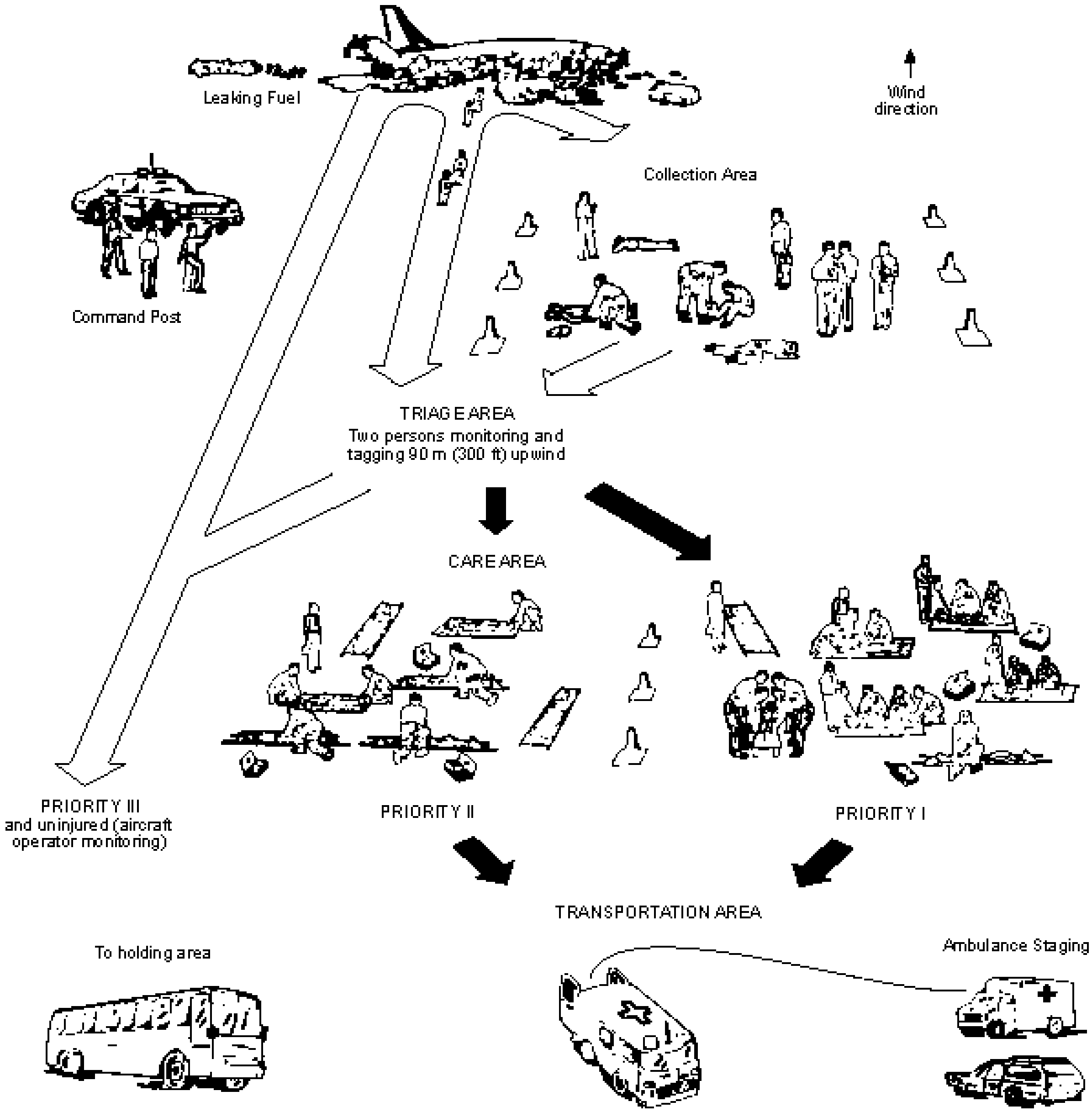


Figure 11-6 Triage and medical care at aircraft accident site.

11-6.1

In the aftermath of an aircraft accident many lives can be lost and many injuries aggravated if immediate medical attention is not provided by trauma-trained rescue personnel. Survivors should be examined, given available emergency medical aid as required, and then promptly transported to appropriate medical facilities.

11-6.2

Triage is the sorting and classification of casualties to determine the order of priority for treatment and transportation. Casualties should be classified into four categories:

Priority I:	Immediate care
Priority II:	Delayed care
Priority III:	Minor care
Priority 0:	Deceased

11-6.3

Triage should begin immediately. Qualified medical personnel should be assigned to this task. Victims are moved from the triage area to the appropriate care holding areas before definitive treatment is rendered. Casualties should be stabilized at the care holding areas and then transported to an appropriate facility.

11-6.4

Every effort should be made to ensure that "immediate" casualties are treated first and receive immediate ambulance transportation priority once they are stabilized. This should be the responsibility of the immediate care leader.

11-6.5

Triage is most efficiently accomplished in place. However, the conditions of an accident scene and wind direction can demand the immediate movement of casualties before triage can be safely accomplished. In that case, the casualties should be moved the shortest distance possible, well away from fire fighting operations, and upwind and uphill from the scene.

11-6.6*

Triage of casualties should include the use of casualty identification tags to aid in the sorting and transportation of the injured to hospitals. This technique is especially suited to multilingual situations.

11-7 Care Principles.

11-7.1

Stabilization of the seriously injured should be accomplished at the accident scene. The immediate transportation of the seriously injured before stabilization should be avoided.

11-7.2

In accidents occurring on or adjacent to the airport, rescue and fire fighting personnel are generally the first emergency personnel on the scene. It is imperative that seriously injured casualties be located and stabilized as quickly as possible. In cases where fire control or prevention does not require the efforts of all rescue and fire fighting personnel, casualty stabilization should be commenced immediately under the direction of the most qualified trauma-trained individual on the scene. First response rescue vehicles should carry initial supplies of victim-care equipment, including artificial airways, compresses, bandages, oxygen, and other related equipment used for the stabilization of smoke inhalation casualties and severe trauma. Sufficient oxygen should be available for use of rescue and fire fighting personnel.

11-7.3

Usually, the first few minutes of medical treatment are aimed at stabilizing the casualties until more qualified medical care is available. When specialized trauma teams arrive, medical care should be more sophisticated.

11-7.4

The triage procedure and subsequent medical care should be placed under the command of one authority, the designated medical coordinator, upon arrival. Prior to arrival, the command of triage should be assumed by the designee of the incident commander until relieved by the predesignated medical coordinator.

11-7.5

The medical coordinator should report directly to the incident commander and has responsibility for all medical aspects of the incident. The primary function should be administrative, not as a participant of the medical team treating the injured.

11-7.6

For distinctive and easy identification, the medical coordinator should wear a standard distinctive uniform. In addition, the Plan should provide for a highly visible vest, or other apparel, with reflective lettering, front and back, that reads "MEDICAL COORDINATOR," or other appropriate lettering, given the terminology used in the Plan.

11-7.7 Care of Priority I "Immediate" Casualties.

This type of casualty includes but is not necessarily limited to:

(a) Major hemorrhages;

(b) Severe smoke inhalation;

(c) Asphyxiating thoracic and cervico-maxillo-facial injuries;

(d) Cranial trauma with coma and rapidly progressive shock;

(e) Open fractures and compound fractures;

(f) Extensive burns (more than 30 percent);

(g) Crush injuries including internal organs;

(h) Any type of shock; and

(i) Spinal cord injuries.

11-7.8 Care of Priority II "Delayed" Casualties.

This type of casualty includes but is not necessarily limited to:

(a) Nonasphyxiating thoracic trauma;

(b) Closed fractures of the extremities;

(c) Limited burns (less than 30 percent);

(d) Cranial trauma without coma or shock; and

(e) Injuries to soft parts.

11-7.9

Care of casualties sustaining injuries that do not need emergency medical treatment to sustain life can be delayed until Priority I casualties are stabilized. Transportation of Priority II casualties should be performed following minimum care given on the site.

11-7.10 Care of Priority III "Minor" Casualties.

This type of casualty includes minor injuries only. Certain accidents/incidents will occur where passengers have either minor injuries or no injuries, or appear to be uninjured. Because this type of casualty can interfere with other priorities and operations it is important that these passengers be transported away from the accident/incident site to the designated passenger holding area where they can be re-examined.

11-7.11

It is important that provisions be made for Priority III casualty care, comfort, and identification. This should be provided through the aircraft operator, where involved, airport operations, or international relief organizations (Red Cross, etc.). Specific treatment areas such as an empty hangar, a designated area in a passenger terminal, a fire station, or other available sites of adequate size (hotel, school, etc.) should be predesignated for this purpose. Any such area selected should be equipped with heating or cooling systems, electric light and power, water, and toilet facilities. Adequate telephones should be available. A number of such preselected sites should be chosen so that when an accident occurs, the most convenient in regard to travel distance and space needs (number of casualties involved) can be selected. All aircraft operator personnel and airport tenants should know the location of such designated facilities.

11-8 Control of the Flow of the Injured.

11-8.1

The injured should pass through four areas that should be carefully located and easily identified (*see Figure 11-6*).

(a) *Collection area* — The location where initial collection of the seriously injured from the aircraft or debris is accomplished. Need for the establishment of this area will be dependent upon the type of accident and the circumstances surrounding the accident site. Custody of casualties is normally transferred from fire rescue personnel to medical services at this point.

(b) *Triage area* — The triage areas should be located at least 90 m (300 ft) upwind of the accident site if fire and smoke is imminent. If necessary, more than one triage area may be established.

(c) *Care area* — Initially this will be a single care area only. Subsequently it should be subdivided into three subareas according to the three categories of injured, i.e., Immediate Care (Priority I), Delayed Care (Priority II), and Minor Care (Priority III). Care areas can be identified by colored traffic cones, bicycle flags, colored blankets, etc. (Red — Immediate, Yellow — Delayed, and Green — Minor).

(d) *Transportation area* — A transportation area for the recording, dispatching, and evacuation of survivors should be located between the care area and the egress road. Only one transportation area is normally required; however, if there is more than one transportation area it is essential to have communication between them.

11-8.2

In remote areas, where transportation to appropriate medical facilities will be delayed, or where climatic conditions dictate, consideration should be given to the provision of mobile quarters for the stabilization and medical treatment of immediate care and delayed care casualties. Ideally these quarters should be operational upon arrival or in less than half an hour. Their design should therefore permit rapid response to the site and rapid activation to receive casualties. [*See definition of Mobile Emergency Hospital (MEH), A-11-1.1*.]

11-9 Standardized Casualty Identification Tags.

11-9.1 Need for Standardized Tags.

Casualty identification tags should be standardized through color coding and symbols to make the tags as simple as possible. Tags can help to expedite the treatment of mass casualties in a triage situation and thus permit more rapid evacuation of the injured to medical facilities.

11-9.2 Tag Design.

Standardized tags that require only minimal information to be entered thereon, are usable under adverse weather conditions, and are water resistant have been designed. An example of such a tag is illustrated in Figures A-11-6.6(a) and (b). In this tag, numerals and symbols indicating medical priority classify casualties as follows:

Priority I or immediate care: RED colored tag;
roman numeral I;
rabbit symbol.

Priority II or delayed care: YELLOW colored tag;
roman numeral II;
turtle symbol.

Priority III or minor care: GREEN colored tag;
roman numeral III;
ambulance with X symbol.

Priority 0 or deceased: BLACK colored tag;
cross symbol.

11-9.3

Where tags are unavailable, casualties can be classified using roman numerals on adhesive tape or by markings made directly on the forehead or on other exposed skin area to indicate priority and treatment needs. Where marking pens are unavailable, lipstick can be used. Felt-tipped pens are not advisable as they may smear in rain, snow, and under other climatic and body conditions.

11-10 Medical Care of Ambulatory Survivors.

11-10.1

The aircraft operator (where involved), the airport authority, or other predesignated agency selected for the purpose should be available to:

(a) Select from among the predesignated passenger holding areas designated in the airport/community emergency plan the most suitable area for the particular emergency;

(b) Provide for the transportation of uninjured passengers from the accident site to the designated holding area;

(c) Arrange for doctors, nurses, or emergency medical personnel teams qualified in first aid to examine and treat supposedly uninjured passengers, especially for nervous traumatism (shock), and smoke inhalation where pertinent;

(d) Interview uninjured passengers and record their names, addresses, and phone numbers, and where they can be reached for the next 72 hours;

(e) Notify relatives or next of kin where deemed necessary;

(f) Coordinate efforts with the designated welfare agency (Red Cross, etc.); and

(g) Provide security from unauthorized interference by persons not officially connected with the rescue operation in progress.

11-10.2

Prearrangements should be made for the immediate transportation by bus or by other suitable transport of the walking wounded and uninjured from the accident site to the designated holding area. This plan should be implemented automatically following notification of the emergency. A nurse or a person trained in first aid should accompany these survivors to the holding area. Each and every passenger should be examined for shock and smoke inhalation. Cold or inclement weather can require additional provisions for the passengers' protection and comfort.

11-10.3

Occupants evacuating an aircraft might have been barefoot when evacuation slides were used and also might be without proper wearing apparel. Prior planning should recognize this potentiality, and emergency footwear, eyeglasses, clothing, and blankets should be available to take care of this situation. Where the aircraft accident occurred in water or in a marshy area, survivors will be wet and uncomfortable. Where such potentials exist, it may be necessary to establish a special designated staging area where survivors can be stabilized prior to transporting them to the normal holding area and to preplan provision for blankets and temporary protective clothing to prevent hypothermia.

Chapter 12 Care of Deceased (Black Tag, Cross Symbol)

12-1 Basis for Recommendations.

12-1.1*

The concept of preservation of evidence should be applied when caring for the deceased at an aircraft accident site. It is important to realize that an undisturbed site can produce the most reliable evidence for determining cause and corrective action that would help prevent a similar incident in the future.

The Plan should include contingencies that address management of the deceased at the scene of the emergency. The Plan needs to designate the person responsible for contacting and coordinating with the medical examiner/coroner.

12-2 Care Prior to Site Investigation.

12-2.1

Airport fire fighters and other rescue personnel should understand the basic need for and the techniques and procedures used in aircraft accident investigation. Wherever possible, the wreckage should remain undisturbed until the arrival of the appropriate investigating agency.

12-2.2*

Areas immediately surrounding the location of the deceased should be completely secured. Areas where a large number of deceased or dismembered casualties are located should be left undisturbed until the arrival of the forensic doctor and the National Transportation Safety Board investigator or his or her designee.

12-2.3

If it becomes necessary to move bodies or parts of the wreckage, photographs should be taken showing their relative position within the wreckage, and a sketch of their respective positions prior to removal should be made. In addition, tags should be affixed to each body or part of the wreckage that was displaced, and corresponding stakes or tags should be placed where they were found in the wreckage. A journal should be kept of all tags issued. Special precautions should be taken to avoid disturbing anything in the cockpit area. Should any control be displaced, photographs, drawings, or notes should be taken.

12-2.4

Extrication of the deceased and removal of personal effects prior to the arrival of the coroner or appropriate authority should be performed only when necessary to prevent their destruction by fire or other similar compelling reasons. Where bodies must be moved, previously mentioned precautions should apply. Provisions should be made to obtain sufficient body bags to contain all bodies as well as personal effects.

12-2.5

Body bags are normally available from major local suppliers of caskets, funeral directors and their equipment and supply firms, and from nearby military facilities. Stocks of body bags at each airport are desirable.

12-3 Care after Site Examination.

12-3.1

Body identification and determination of cause of death should be conducted with the concurrence of the authority designated for this duty. This operation is generally conducted with the cooperation of forensic teams and other specialists.

12-3.2

Accidents that produce a large number of fatalities can overload normal morgue facilities. In areas where delay or temperature can contribute to the deterioration of tissue, refrigerated storage should be available. This can be provided either through a permanently located cooler or refrigerated semitrailers. The area for postmortem examination should be located near the refrigerated storage and should be arranged to provide a high level of security. This area should be large enough for initial body sorting. Electricity and running water should be provided, in addition to a suitable working area.

12-3.3

The morgue should be isolated and in an area remote from places where relatives or general public have access.

12-3.4

After identification of victims, efforts to contact next of kin should commence. Agencies such as aircraft operators representatives, public service organizations (i.e., Red Cross, Salvation Army), or clergy should be utilized.

12-3.5

The accident investigation team generally has the authority to require autopsies and toxicological analyses on crew members, and in special cases, passengers. The need for these tests should be established prior to the release of bodies.

12-3.6

As soon as practical after the emergency, all participants in the fire fighting and rescue effort should be debriefed. Their observations should be recorded by the proper authorities. Sketches, diagrams, photographs, movie films, and tape and video recordings made on the accident site as well as appropriate details on the tagging of bodies and parts of the wreckage removed from their position can be invaluable tools for investigators.

Chapter 13 Airport/Community Emergency Plan Exercise

13-1 Emergency Plan Exercise.

13-1.1

The purpose of an airport/community emergency plan exercise is to test the adequacy of the following:

(a) The airport/community emergency plan and related procedures;

(b) Response of all personnel involved; and

(c) Emergency equipment and communications.

13-1.2

It is therefore important that the Plan contain procedures requiring that the airport/community emergency plan be tested so as to correct as many deficiencies as possible and to familiarize all personnel and agencies concerned with the airport environment, the other agencies, and the role of each agency/person in the emergency plan.

13-2 Need for and Types of Airport/Community Emergency Plan Drills.

13-2.1

The airport/community emergency plan should be subject to full-scale emergency exercises to test all facilities and associated agencies at intervals of about one year. The exercise should be followed by a full debriefing, critique, and analysis. Representatives of all organizations that participate in the exercise also should actively participate in the preparation for the exercise and the final critique.

13-2.2

It is important that small-scale simulated emergency exercises be held at more frequent intervals than the full-scale emergency exercise. These more frequent exercises should be aimed at testing and reviewing the response of individual participating agencies, such as the rescue and fire fighting service, as well as parts of the plan such as the communications system.

13-2.3

It is desirable that, in addition to the full-scale and simulated emergency exercises, a "tabletop" exercise, involving the airport/community emergency plan coordinating committee, be held at least annually but not coincidental with any of the above emergency exercises.

13-3 Planning for Full-Scale Emergency Exercises.

13-3.1

The first step in planning full-scale emergency exercises should be to have the support of all airport and community authorities concerned.

13-3.2

Each agency head should be thoroughly familiar with the airport/community emergency plan and should develop a plan for his or her department in coordination with the general plan. The agency heads should meet in regular sessions to develop an understanding of their agencies' responsibilities and requirements in cooperation with other agencies.

13-3.3

An aircraft representative of the largest aircraft using the airport should be sought for the full-scale emergency exercise to add realism to the exercise and to familiarize participants with the problem of removing casualties from aircraft. If an aircraft is not available, a bus or similar large vehicle can be used.

13-3.4

The emergency exercises should be held in locations that will provide maximum realism while ensuring minimum disruption to the operations of the airport or the orderliness of the community.

13-3.5

At least 120 days prior to the scheduled full-scale emergency exercise, a meeting of all key supervisory personnel of principal participating agencies should be called by the authority in charge. At this time, the aims of the exercise should be outlined, a scenario formulated, work tasks assigned, and duties of all agencies and personnel defined. A suggested time schedule and checklist are as follows:

120 days prior	Organizational meeting of supervisory personnel of participating agencies. Aims outlined, scenario formulated, work tasks assigned, emergency plan coordinators selected.
90 days prior	First progress report on arrangements.

70 days prior	First meeting of all participating agencies (individual committee representatives).
60 days prior	Complete arrangements for full-scale emergency exercise site or staging area. Written scenario completed.
50 days prior	Training for moulage team begins. Second meeting of the individual committee representatives. A moulage chairperson can be selected from hospitals, rescue and fire fighting personnel, civil defense, military personnel, etc.
40 days prior	Arrangements for transportation, feeding, stretcher bearers, and volunteer workers completed.
30 days prior	Third meeting of the individual committee representatives. A preliminary “warm-up” communications exercise is held.
21 days prior	Fourth meeting of the individual committee representatives. Make-up team training and arrangements for volunteer casualties completed.
14 days prior	Final meeting and briefing for all participants, including critique team.
7 days prior	Final meeting of supervisory personnel to review assignments.
Day of exercise	
1–7 days after	A critique following the exercise so that all participants can hear the observers’ reports.
30 days after	The supervisory personnel meet to review written critiques submitted by observers and participants and revise procedures to correct mistakes and shortcomings indicated in the exercise.

13-3.6

In preparing the scenario, the use of real names of aircraft operators and types of aircraft should be avoided. This will prevent any possible embarrassment to companies or agencies involved in civil aviation.

13-3.7

In order to obtain the maximum benefit from a full-scale emergency exercise, it is important to review the entire proceedings. An observer critique team comprised of members who are familiar with mass casualty accident proceedings should be organized. A chairperson of the team should be appointed and should be present at all meetings. The team should be present at the final organizational meeting (seven days prior to the exercise) and, in coordination with the authority in charge, ensure that significant problems are introduced into the exercise. Each member of the critique team should observe the entire exercise and complete the appropriate emergency exercise critique forms.

13-4 Review of the Airport Emergency Plan Drill.

13-4.1

Experience has shown that quite often the provisions set forth in the airport emergency plan are found not to be practical during an exercise or an actual emergency, resulting in confusion and undue inefficiency by some of the participants.

13-4.2*

A critique and review of the procedures followed by the participants in an emergency exercise or an actual accident/incident should be scheduled as soon as all data can be acquired from all agencies. This critique should be held not more than seven days after the exercise or emergency.

13-4.3

The airport authority should make every effort to contact other airport authorities involved in actual aircraft accidents and those who have conducted full-scale emergency exercises to acquire data and procedures to correct and upgrade their airport emergency plan.

Appendix A Explanatory Material

This Appendix is not part of the recommendations of this NFPA document but is included for informational purposes only.

A-1-3 Approved. The National Fire Protection Association does not approve, inspect, or certify any installations, procedures, equipment, or materials; nor does it approve or evaluate testing laboratories. In determining the acceptability of installations, procedures, equipment, or materials, the authority having jurisdiction may base acceptance on compliance with NFPA or other appropriate standards. In the absence of such standards, said authority may require evidence of proper installation, procedure, or use. The authority having jurisdiction may also refer to the listings or labeling practices of an organization concerned with product evaluations that is in a position to determine compliance with appropriate standards for the current production of listed items.

A-1-3 Authority Having Jurisdiction. The phrase "authority having jurisdiction" is used in NFPA documents in a broad manner, since jurisdictions and approval agencies vary, as do their responsibilities. Where public safety is primary, the authority having jurisdiction may be a federal, state, local, or other regional department or individual such as a fire chief; fire marshal; chief of a fire prevention bureau, labor department, or health department; building official; electrical inspector; or others having statutory authority. For insurance purposes, an insurance inspection department, rating bureau, or other insurance company representative may be the authority having jurisdiction. In many circumstances, the property owner or his or her designated agent assumes the role of the authority having jurisdiction; at government installations, the commanding officer or departmental official may be the authority having jurisdiction.

A-2-1 Outline of an Airport/Community Emergency Plan. This guideline is intended to ensure uniformity in the development of airport/community emergency plans. It is the function of the airport authority to develop a plan and procedures for emergencies applicable to the airport's particular characteristics and operations and, within these guidelines, to perform the following:

(a) Define the responsibilities of the airport authority and other participating agencies;

(b) Create effective lines of communication and adequate communication facilities as indicated by a flow chart; and develop a call system to include persons or agencies to be contacted. Where possible, a 24-hour coverage should be maintained;

(c) Arrange for the availability of a fixed emergency operations center and a mobile command post at the airport for use during an emergency;

(d) Integrate assistance from local support services such as fire departments, security, medical, civil defense, government agencies, and local amateur radio organizations, etc.;

(e) Describe the function of air traffic control services (airport control tower or airport flight information service) relating to emergency actions; and

(f) Give instructions for response to accidents/incidents.

Sections of the airport/community emergency plan document should contain identifiable subjects pertinent to local airport and community conditions.

The emergency plans and procedures should be issued under the airport or appropriate authority, who will define and negotiate functions of all agencies and personnel on or off the airport who would or could be involved in an emergency affecting the airport.

In developing the emergency plan and procedures, it is vital that arrangements be simple and easily understood by all involved in the Plan.

Example of Contents of Emergency Plan Document:

Section 1 — Emergency Telephone Numbers. This section should be limited to essential telephone numbers according to site needs, including:

(a) Air traffic control services;

(b) Rescue and fire fighting services (departments);

(c) Police and security;

(d) Medical services;

1. Hospitals

2. Ambulances

3. Doctors — business/residence

(e) Aircraft operators;

(f) Government authorities;

(g) Civil defense;

(h) Others.

Section 2 — Aircraft Accident on the Airport. This section should detail the:

(a) Action by air traffic control services (airport control tower or airport flight information service);

(b) Action by rescue and fire fighting services;

(c) Action by police and security services;

(d) Action by airport authority;

1. Vehicle escort
2. Maintenance

(e) Action by medical services;

1. Hospitals
2. Ambulances
3. Doctors
4. Medical personnel

(f) Action by aircraft operator involved;

(g) Action by emergency operations center and mobile command post;

(h) Action by government authorities;

(i) Communications network (emergency operations center and mobile command post);

(j) Action by agencies involved in mutual aid emergency agreements;

(k) Action by transportation authorities (land, sea, and air);

(l) Action by the public information officer(s);

(m) Action by local fire departments when structures are involved;

(n) Action by all other agencies.

Section 3 — Aircraft Accident off the Airport. This section should detail the:

(a) Action by air traffic control services (airport control tower or airport flight information service);

(b) Action by rescue and fire fighting services;

(c) Action by local fire departments;

(d) Action by police and security services;

(e) Action by airport authority;

(f) Action by medical services;

1. Hospitals
2. Ambulances
3. Doctors
4. Medical personnel

(g) Action by agencies involved in mutual aid emergency agreements;

(h) Action by aircraft operator involved;

(i) Action by emergency operations center and mobile command post;

(j) Action by government authorities;

(k) Communication networks (emergency operations center and mobile command post);

(l) Transportation authorities (land, sea, and air);

(m) Action by public information officer;

(n) Action by all other agencies.

Section 4 — Malfunction of Aircraft in Flight (Full Emergency or Local Standby). This section should detail the:

(a) Action by air traffic control services (airport control tower or airport flight information service);

(b) Action by airport rescue and fire fighting services;

(c) Action by police and security services;

(d) Action by airport authority;

(e) Action by medical services;

1. Hospitals
2. Ambulances
3. Doctor
4. Medical personnel

(f) Action by aircraft operator involved;

(g) Action by emergency operations center and mobile command post;

(h) Action by all other agencies.

Section 5 — Structural Fires. This section should detail the:

(a) Action by air traffic control services (airport control tower or airport flight information service);

(b) Action by rescue and fire fighting services (local fire departments);

(c) Action by police and security services;

(d) Action by airport authority;

(e) Evacuation of structure;

(f) Action by medical services;

1. Hospitals
2. Ambulances
3. Doctors
4. Medical personnel

(g) Action by emergency operations center and mobile command post;

(h) Action by public information officer;

(i) Action by all other agencies.

Section 6 — Sabotage Including Bomb Threat (Aircraft or Structure). This section should detail the:

(a) Action by air traffic control services (airport control tower or airport flight information service);

(b) Action by emergency operations center and mobile command post;

(c) Action by police and security services;

(d) Action by airport authority;

(e) Action by rescue and fire fighting services;

(f) Action by medical services;

1. Hospitals
2. Ambulances
3. Doctors
4. Medical personnel

(g) Action by aircraft operator involved;

(h) Action by government authorities;

(i) Isolated aircraft parking position;

(j) Evacuation;

(k) Searches (dog and human) of helicopter aircraft;

(l) Handling and identification of luggage and cargo on board aircraft;

(m) Handling and disposal of suspected bomb;

(n) Action by public information officer;

(o) Action by all other agencies.

Section 7 — Unlawful Seizure of Aircraft (Hijacking). This section should detail the:

(a) Action by air traffic control services (airport control tower or airport flight information service);

(b) Action by rescue and fire fighting services;

(c) Action by police and security services;

(d) Action by airport authority;

(e) Action by medical services;

1. Hospitals
2. Ambulances
3. Doctors
4. Medical personnel

(f) Action by aircraft operator involved;

(g) Action by government authorities;

(h) Action by emergency operations center and mobile command post;

(i) Isolated aircraft parking position;

(j) Action by public information officer;

(k) Action by all other agencies.

Section 8 — Incident on the Airport.

An incident on the airport can require any or all of the action detailed in "Aircraft Accident on the Airport." Examples of incidents the airport authority should consider include fuel spills at the ramp, passenger loading bridge, and fuel storage area; dangerous goods (hazardous materials) occurrences at freight handling areas; collapse of structures; vehicle/aircraft collisions, etc.

Section 9 — Persons of Authority — Site Roles.

To include but not be limited to the following according to local requirements:

(a) On-airport;

1. Airport authority
2. Airport chief fire officer
3. Police and security — officer-in-charge
4. Medical coordinator

(b) Off-airport;

1. Local chief fire officer
2. Government authority

3. Police and security — officer-in-charge

4. Medical coordinator.

The incident commander should be designated as required from within the prearranged mutual aid emergency agreement.

Previous documented experience indicates that confusion in identifying command personnel in accident situations is a serious problem. To alleviate this problem it is suggested that distinctive colored vests with reflective lettering be issued to command personnel for easy identification. The following colors are recommended:

RED	— CHIEF FIRE OFFICER
BLUE	— POLICE CHIEF
WHITE (RED LETTERING)	— MEDICAL COORDINATOR
INTERNATIONAL ORANGE	— AIRPORT ADMINISTRATION
LIME GREEN	— TRANSPORTATION OFFICER
DARK BROWN	— FORENSIC CHIEF

An incident commander should be appointed as the person in command of the overall emergency operation. The incident commander should be easily identifiable and can be one of the persons indicated above or any other person from the responding agencies.

A-2-2 Types of Alerts. The terms used to describe various categories of aircraft alerts are not standardized. The Federal Aviation Administration (FAA) terms — Alert I, Alert II, or Alert III — and the International Civil Aviation Organization (ICAO) terms — Local Standby, Full Emergency, and Aircraft Accident—are equivalent.

Alert I — Local Standby. An aircraft that is known or suspected to have an operational defect should be considered local standby. This defect normally should not cause serious difficulty in achieving a safe landing.

Alert I also should be initiated when an aeromedical evacuation or presidential/VIP aircraft is arriving or departing.

Airports should have management policies for implementation of Alert I procedures whenever required response times cannot be achieved. Factors that can affect response time include construction work, field maintenance, and adverse weather conditions such as snow, ice, or low visibility.

Airports should have management policies for implementation of Alert I procedures during arrival and departures of certain categories or types of aircraft not normally utilizing the airport.

Under Alert I conditions, at least one aircraft rescue and fire fighting vehicle should be manned and positioned to permit immediate use in the event of an incident. The Aircraft Rescue and Fire Fighting (ARFF) personnel should be advised of:

(a) The type of aircraft;

(b) The number of passengers and crew;

(c) The type and amount of fuel;

(d) The nature of the emergency;

(e) The type, amount, and location of dangerous goods; and

(f) The number of nonambulatory passengers on board, if any.

All other ARFF vehicles should be available for immediate response.

Alert II — Full Emergency. An aircraft that is known or is suspected to have an operational defect that affects normal flight operations to the extent that there is danger of an accident is an Alert II — Full Emergency. ARFF personnel should be provided with detailed information that allows preparation for likely contingencies. A full response should be made with the emergency equipment manned and positioned with engines running and all emergency lights operating so that the fastest response to the incident/accident site can be accomplished. It is important that appropriate radio frequencies be continuously monitored by ARFF personnel. One or more major aircraft rescue and fire fighting vehicles should be able to initiate fire suppression within the briefest period of time following the aircraft's coming to rest. Standby positioning of vehicles should be established for a variety of anticipated circumstances. The ARFF personnel should be informed of any changes in a distressed aircraft's emergency conditions that could affect the touchdown point or the ultimate behavior of the aircraft.

Alert III — Aircraft Accident/Fire. This alert denotes an aircraft accident or serious aircraft fire has occurred on or in the vicinity of the airport. Regardless of the source of this alarm, full airport fire and rescue response procedures should be put into effect. Where possible, all known pertinent information should be relayed via radio by Air Traffic Control (ATC) to responding emergency units and include as accurately as possible the location of the accident using grid-map coordinates and landmarks.

Where such information is not available, the ARFF personnel should anticipate the worst situation and prepare accordingly.

The officer in charge should advise ATC of conditions at the site, particularly if such conditions could interfere with flight operations.

Emergencies not involving aircraft include:

(a) Nonaircraft accident related airport emergencies;

(b) Natural disasters; and

(c) Medical emergencies.

A-3-3.1 For a comprehensive description of training and skills required see NFPA 1003, *Standard for Airport Fire Fighter Professional Qualifications.*

A-3-8 Responsibilities of Aircraft Operations Personnel Following an Aircraft Accident. Airline personnel often are the only force on the airport available for quick response to passenger service in an emergency since fire, police, and airport operation departments are usually required to respond to the accident site.

An air carrier emergency plan should be coordinated with the airport/community emergency plan so that airline personnel know which responsibilities the airport will assume and what response is required by the airline. A checklist form should be developed by the airline for the company coordinator's use. This form should be time correlated to the documented notification time of the accident, company communications, personnel assignments, response, and other actions taken. From this log of events a critique of airline and airport/community emergency plans can be analyzed for future improvement.

Training should be initiated by the airlines to prepare all station personnel for emergency procedures. In all emergencies the individuals involved are subjected to stresses of a severity not generally encountered. It is vital for all emergency workers to be familiar with common responses by the individuals to unusual stress and apprehension and to be able to cope effectively with disturbed persons. The best possible preparation for effective behavior under disaster conditions is education and practice. Education should include instructions in the nature and actions of disturbed individuals and the general type of reaction to be expected from each. There should be participation in simulated emergency exercises to help establish effective patterns of behavior under emergency conditions and practice the basic principles of "psychological first aid."

A holding area for uninjured persons should be designated in order to assemble and process passengers not injured in the emergency. The area selected should provide for both passenger comfort and security from the news media. Upon notification of an accident, designated airline personnel should immediately respond to the holding area to receive the passengers evacuated from the accident scene. The airline personnel should be at this station before the passengers arrive. Emergency kits should be prepared and be readily available for the passenger service representatives to effectively carry out their duties. While waiting for the evacuees, an organizational meeting should be held by the person in command, delegating a receptionist, registrar, and welfare coordinator for the survivors.

The following organization and description of required duties are suggested:

The Airline Coordinator. Normally this would be the senior representative from the airline whose aircraft had the accident. In the event of a charter or nonscheduled flight, the representative of the airline designated to provide ground services for that flight should take charge. In the event of an over-flight or carrier without personnel based at the airport, representative authority would have to be determined by those responding. The person in charge should have radio communication to the airline operations or other designated emergency center. Telephones should be available in the holding areas. The person in command oversees the overall airline operations, making arrangements for additional medical services if required, commissary items, etc.

The receptionist should meet the buses as they arrive from the scene of the accident and direct the passengers to the registrars' tables where they will be processed. The receptionist should know where toilet facilities are located.

Registrars. The registrars should have emergency kits available to them. Two people should constitute one registrar team. Several teams can be required to process the passengers swiftly and efficiently. One member should enter the passenger's name on the manifest and determine what reservation requirements are desired, i.e., hotel accommodations or another flight, transportation, etc., and any persons to be notified of the passenger's condition and plans. The other member of the registrar team should make out an identification tag or sticker (available from the emergency kit) and place it on the passenger. This can assist in identifying the passenger when accommodations have been made. More importantly this will indicate that the passenger has been processed. The registrars should direct the victims to the welfare coordinators when their registration is completed.

Welfare coordinators are the nucleus of psychological first aid. They should attempt to stimulate passenger discussion. Special attention should be given to those who do not join in the group. In giving psychological first aid, it should be noted that some persons become more disturbed than others. Giving those persons sympathetic understanding can be the first step toward helping them. Overwhelming victims with pity may only increase their fear and feelings of helplessness. A person who exhibits bodily trembling, rapid breathing, rapid pulse, shortness of breath, etc., should be engaged in conversation and professional medical attention requested as soon as available.

A sizable personnel force can be provided by most air carriers; however, there can be a problem at airports with a small operation. As a result, a mutual aid assistance program of all airline personnel (and, if necessary, other airport tenants based at the airport) should be established. Training can be acquired from local mental health care and Red Cross units. This training is not extensive but would provide education for passenger service in an emergency. In addition to care for the victims evacuated from an accident site, training also should include a possible traumatic situation that could develop in the gate area of the terminal building.

Emergency Kits. Each airline should prepare an emergency kit that can be readily available to all airline personnel during all hours of operation. This kit should never be placed in an office that is locked during certain hours of the day. All station personnel should have knowledge of the location of the emergency kit. The contents of the kit should include:

(a) Tablets or forms to record the victims' names, addresses, and home phone numbers; name and phone number of person to be notified of passenger’s condition; accommodation request of passenger (i.e., future flight, hotel, transportation within the local area, etc.).

(b) Stick-on, adhesive-type name tags to identify passengers who have been processed and for identification of victim when accommodations have been made.

(c) Telephone numbers of:

1. Doctors to attend to minor injuries. Each airline should have a letter of agreement with physicians who will respond to a designated holding area.

2. Hotels where victims can be billeted. It is beneficial to place victims in the same hotel or at least in groups at hotels.

3. Linguists. Preferably people who work on the airport for quick response.

4. Caterer if commissary items are required.

5. All airline reservations offices.

6. Ambulance companies in case a victim requires hospitalization.

7. Taxicab companies.

(d) A current copy of the *Official Airline Guide* (OAG). Local airline schedules can be helpful for registrars who will be making arrangements on future flights.

(e) Sample of Registrar’s Form:

Passenger
NAME________________________
ADDRESS ____________________
PHONE NUMBER______________
ACCOMMODATIONS ______________________________________
__________________ .
Flight __________________ , Hotel, Local Phone Number, etc.

Person(s) to be Notified
NAME______________
RELATION__________
PHONE NUMBER______

Table A-3-8.1 Aircraft Data

Aircraft Type	Span (ft)	Span (m)	Length (ft)	Length (m)	Gross Weight lb	G Wei
AIRBUS IND A-300	147.08	44.83	177.33	54.05	363,800	
A-310	144	43.89	153.08	46.66	305,600	
A-320	111.25	33.91	123.25	37.57	162,000	
ANTONOV AN22	211	64.31	167	50.90	500,000	
ANTONOV AN225	290	88.39	275.58	84.00	1,000,000	
ATR 72	88.58	27.00	89.08	27.15	44,100	
BEECHCRAFT 1900	54.5	16.61	57.83	17.63	16,600	
BEECHCRAFT KING AIR (350)	57.92	17.65	46.67	14.23	15,000	
BOEING 727	108	32.92	153.17	46.69	191,000	
BOEING 737-300	94.67	28.86	119.5	36.42	139,000	
BOEING 747-400	211	64.31	231.75	70.64	870,000	
BOEING 757	124.67	38.00	155.25	47.32	240,000	
BOEING 767-300 ER	156.08	47.57	180.25	54.94	407,000	
BRITISH AEROSPACE/CONCORDE AEROSPATILE	83.67	25.50	203.67	62.08	408,000	
CASA 235 CN235	84.5	25.76	70	21.34	31,746	
CESSNA CITATION 5	53.42	16.28	48.67	14.83	16,100	
DEHAVILLAND DASH 8	85	25.91	73	22.25	34,500	
GRUMMAND GULFSTREAM 4	77.67	23.67	88.25	26.90	73,600	
ILYUSHIN-IL86	158.5	48.31	191.75	58.45	413,600	
LOCKHEED L-1011-500	164.25	50.06	164.17	50.04	504,000	
McDONNELL DOUGLAS DC 10-40	165.25	50.37	180.5	55.02	572,000	2

McDONNELL DOUGLAS MD11	169.25	51.59	200.67	61.16	602,500	2
McDONNELL DOUGLAS MD88	107.67	32.82	147.75	45.03	149,500	
SHORT 360	74.83	22.81	70.83	21.59	26,000	1
TUPOLEV Tu154	123.17	37.54	157.17	47.91	198,450	9

A-3-15.1 Mutual Aid Emergency Agreements.

The close proximity of an airport to surrounding communities and the possibility of an off-airport aircraft accident gives rise to the need for mutual aid emergency agreements.

A mutual aid emergency agreement should specify initial notification and response assignments. It should not specify the responsibilities of the agency concerned, as this will be contained in the emergency plan.

Mutual aid emergency agreements should be prearranged and duly authorized. A sample of a letter of agreement is included in Figure A-3-15.1. Should more complicated jurisdictional or multiagency agreements be necessary, the airport authority may have to act as coordinating agency. This appendix contains guidelines compiled to assist with preparation of mutual aid emergency agreements with local fire departments for accidents occurring on and off the airport.

Procedure for Local Fire Department(s) — Aircraft Accident on Airport:

(a) A call to an aircraft accident on the airport will normally be received from air traffic control services.

(b) The mutual aid fire department(s) should report to the rendezvous point or staging area on arrival at the airport. Escort by airport police/security should be provided from the rendezvous point or staging area to the accident site.

(c) Upon arrival at the accident site:

1. The senior officer of the airport rescue and fire fighting service receiving mutual aid should have full authority at the scene unless other laws or agreements contradict this statement.

2. Fire department mutual aid communications should be carried out on the predesignated communications channel.

3. Communications transmissions should be prefaced by an airport rescue and fire fighting or local fire department call number.

AGENCY: (Name and Address)

____

____

____

Endorses the XYZ (International) Airport Emergency Plan, associated airport emergency plan document dated (insert date), and attached procedures (included as A-3-15.1.1 and A-3-15.1.2) and agrees to comply with all the procedures and instructions, and fulfill all applicable responsibilities therein.

____

Signature of Authorized Representative

____

Date

Figure A-3-15.1 XYZ (International) Airport

Emergency Plan

Letter of Emergency Mutual Aid Agreement.[1]

[1]See Appendix E, "Sample Mutual Aid Agreements," of NFPA 402, *Guide for Aircraft Rescue and Fire Fighting Operations*.

Procedure for Local Fire Department(s) — Aircraft Accident off Airport:

(a) A call to an aircraft accident off the airport will normally be received from air traffic control services or police. Should that not be the case, the local fire department should notify air traffic control services or police via radio or telephone that an accident has occurred, giving the approximate location on the grid map.

(b) Upon arrival at the accident site, the local fire department should:

1. Ensure that the mutual aid emergency agreement is initiated.

2. Establish a command post. (This may be a temporary post until the airport authority mobile command post is available and operative.)

3. Ensure that all communications are on the designated aircraft accident channel.

(c) The local fire department should advise air traffic control services or police of the following:

1. Exact location of the accident site.

2. Location of the command post.

3. Specific location/rendezvous points on the grid map to which fire units should respond.

4. Any request for specialized equipment, if necessary.

A-3-16 Aircraft Accidents in the Water. Where airports are situated adjacent to large bodies of water (such as rivers or lakes) or where they are located on coastlines, special provisions should be made for rescue and fire fighting operations in event of an aircraft accident/incident in the water. Specialized equipment for rescue and fire fighting may include fire/rescue boats; air-cushion vehicles (ACV); helicopters; coastal patrol boats; etc. (*See Figure A-3-16.*)

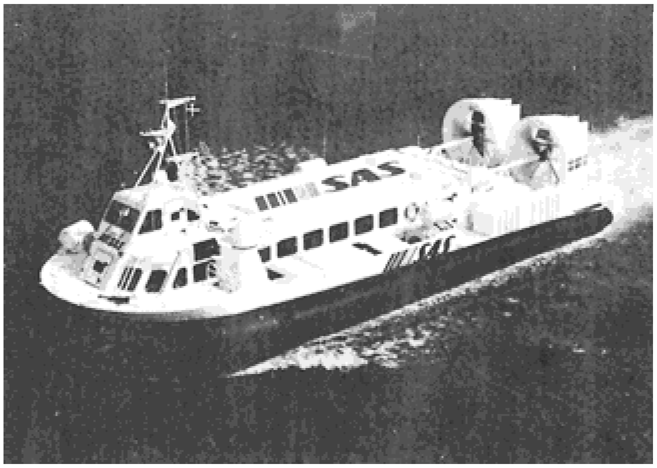


Figure A-3-16 The "Winchester" Class Hovercraft (built by the British Hovercraft Corporation), which is in service at the Auckland International Airport in New Zealand. It is utilized to protect aircraft operations that are largely over the Manukau Harbor that borders the airport. The primary mission is rescue of occupants in the event of an accident in the harbor or mudflats (which exist at low tide).

Consideration of unusual terrain and water conditions, such as tidal flats, swamps, etc., can dictate the choice of the particular type of vehicle most suitable to these conditions. Helicopters and air-cushion and amphibious vehicles as well as conventional watercraft may be found to provide this specialized service.

In developing the water rescue service, consideration should be given to private or public services (such as military search and rescue units, harbor police, or fire departments) and private rescue services (such as rescue squads, power and communication companies, pipeline or oil field operators, lumbering industry, or shipping and waterway operators) that may be available and are capable of rendering assistance. A signal system for alerting private or public services in time of emergency should be prearranged.

Many aircraft do not carry personnel flotation devices on board, especially those not engaged in extensive over-water operations. Such flotation devices should be available in numbers sufficient to meet the needs of the maximum passenger capacity of the largest aircraft in regular service at the airport. Where the largest aircraft is in scheduled over-water operation and all other operations are over-water in character, the airport may reduce the amount of personnel flotation devices by 50 percent.

Probability of Fire. In incidents of aircraft accidents over water, the possibility of fire is normally reduced, hopefully because of the suppression of ignition sources by the water contact and the cooling of heated surfaces. In situations where fire is present, its control and extinguishment present unusual problems unless the proper equipment is available.

Spillage of Fuel on Water Surfaces. It should be anticipated that the impact of the aircraft hitting the water might rupture fuel tanks and lines. It is reasonable to assume that quantities of fuel will thus be found floating on the surface of the water. Boats with exhausts at the waterline can present an ignition hazard if operated where this condition is present. Wind and water currents should be taken into consideration in order to deal effectively with floating fuel to keep it from moving into areas where it would be hazardous to rescue operations or initiate fire. As soon as possible, pockets of fuel should either be broken up or moved with large volume nozzles, neutralized by covering them with foam or a special inerting material, or boomed to contain the fuel in a safe area prior to absorption, dilution, or removal. Preplanning with the EPA's Water Pollution Control Division can provide emergency assistance during this operation.

Rescue Boats. Rescue boats should be capable of shallow water operations. Boats powered by jet-type propulsion eliminate the dangers of propellers puncturing inflatable equipment or injuring survivors during rescue operations. Boats powered by conventional propellers can diminish the hazards of puncture and injury by being equipped with fan-type guards or cowls.

Boats and other rescue vehicles should be located so that they can be brought into action in minimum time, but in any event not more than 15 minutes within the area extending up to 1000 m (3281 ft) from the end of the runway(s). Special boathouses or launching facilities should be provided where they will contribute materially to the rapidity of the launching process.

The boats should be of such size as to carry efficiently the flotation equipment required with adequate space for the crew and sufficient working space to permit rapid dispersal of the flotation devices. Inflatable life rafts should be the prime flotation equipment carried, and there should be an adequate number of life rafts to accommodate the largest aircraft occupancy served by the airport. Once this flotation equipment has been dispensed, there should be sufficient space to accommodate a limited number of litter cases brought aboard in the process of rescue.

In order to permit communications with other rescue units, such as helicopters, air-cushion or amphibious equipment, and water-land based units, adequate two-way radio equipment should be provided in all rescue boats.

A minimum of two floodlights should be provided for night operations.

Radar reflectors should be used to facilitate navigation and rendezvous efforts.

Organizing Diving Units/Use of Divers. Diving units should be dispatched to the scene. Where available, helicopters can be used to expedite the transportation of divers to the actual area of the crash. All divers who may be called for this type of service should be highly trained in both scuba diving and underwater search and recovery techniques. In areas where there are no operating governmental or municipal underwater search and recovery teams, agreements can be made with private diving clubs. The qualifications of the individual divers should be established by training and practical examination.

In all operations where divers are in the water, standard divers' flags should be flown and boats operating in the area should be warned to exercise extreme caution.

Where fire is present, approach should be made after wind direction and velocity and water current and swiftness are taken into consideration. Fire can be moved away from the area by using a sweeping technique with hose streams. Foam and other extinguishing agents should be used where necessary.

It should be anticipated that victims are more apt to be found downwind or downstream. This should be taken into consideration in planning the attack. Where only the approximate location of the crash is established upon arrival, divers should use standard underwater search patterns marking the locations of the major parts of the aircraft with marker buoys. If sufficient divers are not available, dragging operations should be conducted from surface craft. In no instance should dragging and diving operations be conducted simultaneously.

Where occupied sections of the aircraft are found submerged, the possibility remains that enough air may be trapped inside to maintain life. Entry by divers should be made at the deepest point possible.

Other Considerations. Where the distance offshore is within range, synthetic fiber-covered, rubber-lined fire hose can sometimes be floated into position by divers or boats and used to supplement other means of fire attack.

A command post should be established at the most feasible location on the adjacent shore. This should be located in a position to facilitate implementing the airport/community emergency plan in accordance with guidelines established by the authority having jurisdiction.

Great care should be exercised in maintaining the watertight integrity of occupied aircraft sections found afloat. Removal of the occupant(s) should be accomplished as smoothly and quickly as possible. Any shift in weight or lapse in time can result in its sinking, and rescuers should use caution to avoid becoming trapped themselves.

A-4-2.2 See Figure A-4-2.2.

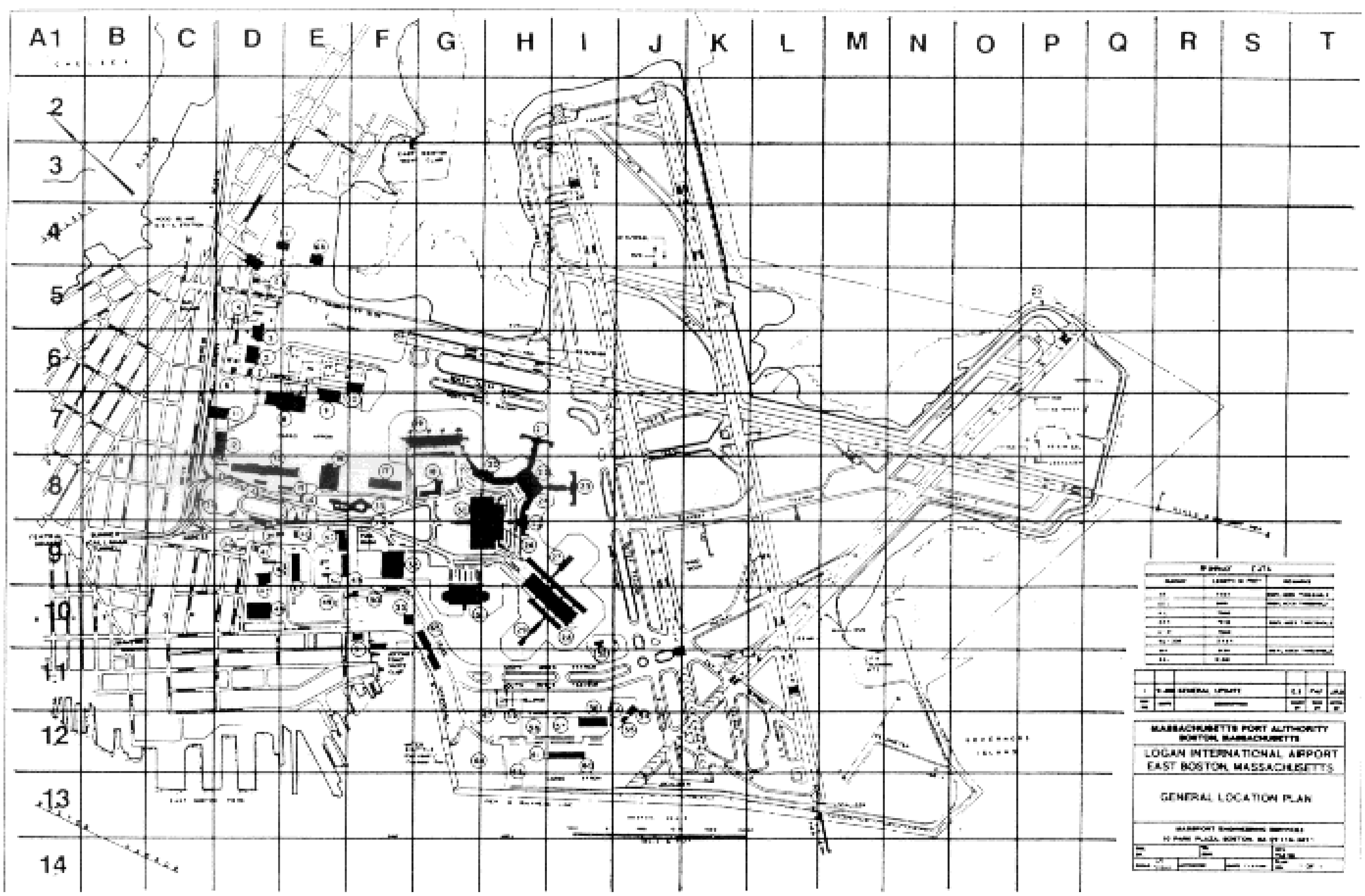


Figure A-4-2.2 Typical airport grid map.

A-5-2.2 See Figure A-5-2.2.

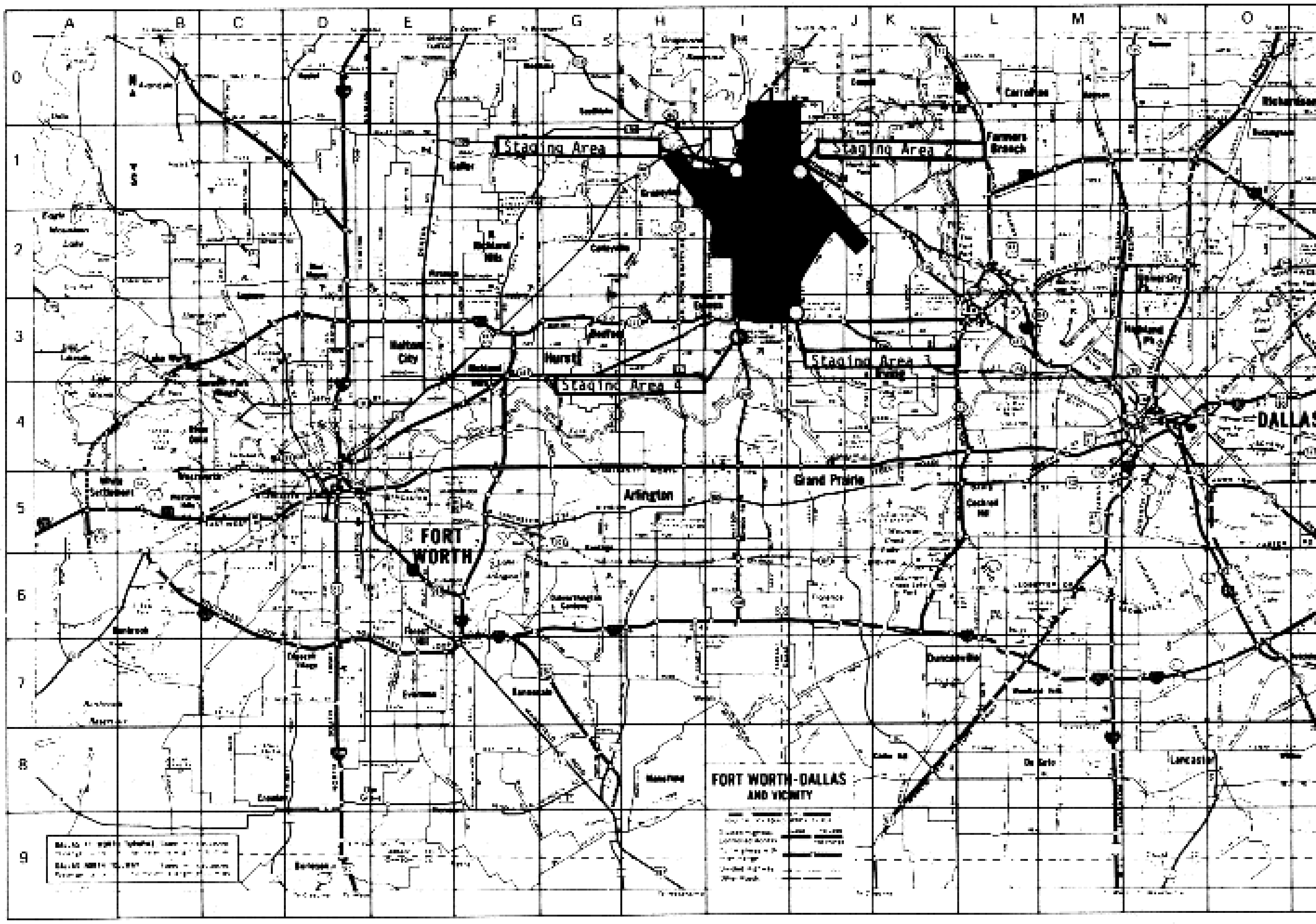


Figure A-5-2.2 Typical airport grid map.

A-5-4.2 The first security officer to arrive should assume security responsibility, survey the scene, and request reinforcements as needed. This security officer should remain in command until relieved by the appropriate security authority with jurisdiction over the area.

The security chief should be highly visible. Typically, a blue industrial hard hat with reflective lettering displayed fore and aft, and imprinted “SECURITY CHIEF,” should be issued to the security officer in charge.

Security personnel and police will be needed to handle traffic, to keep unauthorized personnel from the crash site, and to assume custody of personal effects removed from the aircraft. Ingress and egress roads should be established as congestion-free traffic lanes for emergency vehicles.

Normal traffic should be routed away from and around the crash site.

The emergency site should be cordoned off as soon as possible to exclude intruders, sightseers, onlookers, and souvenir hunters. Appropriate markings should be prominently displayed to advise all persons of possible hazards that can cause serious injury should they encroach on the area.

Arm bands, site passes, or I.D. tags should be issued by the controlling authority and monitored by the security coordinator and his or her team.

A mutual aid program should be instituted between all potentially involved security agencies, e.g., airport, city, county, state, and federal security forces; mail inspectors; and, where appropriate, military police and customs officials.

Special security provisions are necessary to protect any mail involved and any dangerous goods that may be present, and to protect against radioactive materials exposure.

A-5-8.11 For aircraft removal technique, see *International Civil Aviation Organization Airport Services Manual*, Part 5, "Removal of Disabled Aircraft."

A-11-1.1 Airport Medical Services. Medical services and supplies should be available to an airport. Provision of medical services generally should not present great difficulties at large airports or airports near a large city, as the personnel and material normally will be available. What is required is the development of the necessary coordination between the airport and the emergency medical assistance system in the community.

Provision of medical services can present some difficulties at small airports not located near populated areas. These airports, however, should arrange to have available emergency medical services to provide medical care in the event of an aircraft accident, taking into account the largest aircraft using the airport.

The capability of medical personnel can be greatly enhanced by additional resources for improving the environment of the treatment area. Many airport/community areas contain valuable support equipment that is not utilized because it was never determined that such equipment was available. Local agencies such as transportation departments, boards of health, park departments, departments of natural resources, etc., can be good sources. Federal agencies such as the Corps of Engineers, Department of Transportation, and Armed Forces (both active and reserve elements) possess a wide variety of support equipment and material. Examples of support equipment are mobile structures, auxiliary power and heating devices, water tankers, fuel supplies, lighting devices, sawhorses and lighting for roadblocks, etc.

Portable shelters such as mobile hospitals, tents, and recreation vehicles can be used where extremes in climate or weather can affect patient survivability. Consider the use of adjacent buildings such as aircraft hangars, gymnasiums, auditoriums, warehouses, etc., if distance and transportation resources are favorable.

Ideally, all personnel assigned to rescue duties and "public-contact" airport employees should be given first aid and CPR (cardiopulmonary resuscitation) training.

Rescue and fire fighting personnel should have the ability to stabilize seriously injured casualties. At least two full-time members per shift of the airport rescue and fire fighting service or other on-airport personnel should be trained to an emergency medical treatment level as determined by the local medical authority. In addition, it is recommended that as many rescue and fire fighting personnel as is practicable receive training to meet minimum standards of medical proficiency and preferably be highly qualified in first aid; preferably certified as emergency medical technicians. Accordingly, they should have sufficient medical equipment at their immediate disposal to initiate stabilization until transportation of casualties to adequate medical facilities is provided.

As many airport personnel as practicable also should be trained in CPR (cardiopulmonary resuscitation) as taught by the appropriate medical authority. Periodic exercises and drills in CPR techniques are necessary to maintain proficiency.

All rescue, fire fighting, and medical personnel should be trained to protect themselves from the spread of communicable diseases should they become exposed to blood or other body fluids during rescue or emergency medical care activities.

The everyday medical problems at large airports can serve to promote an increased proficiency in emergency medical techniques of airport-based emergency personnel. It should be noted, however, that proficiency in emergency medical techniques can be maintained only through constant practical application. Unless operations include providing advanced life support on a day-to-day basis, proficiency will decline or disappear.

Airports are encouraged to include volunteer on-airport personnel, other than rescue and fire fighting personnel, to provide an auxiliary response to assist casualties resulting from emergencies. Volunteers should be trained by accredited agencies in first aid or rescue response duties. In case of an emergency they should respond to a designated staging area for assignment. The question of liability is a matter for each appropriate authority.

Due to the many conflicting national and international standards and nomenclature of medical personnel, for the purpose of this guide, the following definitions are prescribed as guidelines:

(a) Advanced First Aid: 56 hr instruction.

(b) Emergency Medical Technician (EMT): 114 hr instruction (100 hr classroom; 10 hr hospital emergency room apprentice service; 4 hr ambulance apprentice duty).

(c) Paramedic: 500 hr instruction (200 hr classroom; 100 hr hospital emergency room apprentice service; 200 hr ambulance apprentice duty).

(d) Recurrent training should be provided in each specialty and recertification achieved at least on an annual basis, or as required by the local jurisdiction.

Emergency Medical Supplies and Equipment. The airport authority should arrange to have available on or in the vicinity of the airport sufficient medical supplies to treat the passenger capacity of the largest aircraft normally using the airport. Experience has shown, however, that more than one aircraft can be involved in an aircraft accident, and consequently medical supplies to handle this possibility should be considered. The type and quantity of such supplies should be determined by the principal medical authority for the airport using the statistical information given in Table A-11-1.1(a).

Table A-11-1.1(a) Estimated Maximum Number of Casualties at an Aircraft Accident at an Airport

Aircraft Occupants	Number of Casualties	20 Percent Casualties Immediate Care Priority I	30 Percent Casualties Delayed Care Priority II	50 Percent Casualties Minor Care Priority III
500	124	24	38	62

450	112	22	34	56
400	100	20	30	50
350	87	17	26	44
300	75	15	23	37
250	62	12	19	31
200	50	10	15	25
150	38	8	11	19
100	25	5	8	12
50	12	2	4	6

These figures are based on the assumption that the maximum number of surviving casualties at an aircraft accident occurring on or in the vicinity of an airport is estimated to be no more than 25 percent of the aircraft occupants.

To cope with an emergency involving a large aircraft, it is recommended that the general emergency medical supplies and equipment included in Table A-11-1.1(b) be available at the airport or otherwise be available from outside sources. Table A-11-1.1(b) has been prepared to cope with the largest type of aircraft at present being used for commercial air transport operations, i.e., B747, DC-10, Airbus. If, at any airport, only smaller aircraft will be handled during the foreseeable future, the suggested medical supplies and equipment should be adjusted to the largest aircraft expected to operate at the airport.

Table A-11-1.1(b) General Emergency Supplies and Equipment

Quantity	Description
100	Stretchers, adaptable to the most commonly used ambulances
10	Immobilizing mattresses for backbone fractures
10	Backboards for backbone fractures
50	Splints, either conventional or inflatable, for the various types of fractures
50	First aid kits, each containing a set of 10 tags, haemostatic pads, tourniquets, respiratory tube, scissors, dressings
20	Resuscitation chests containing material for intubation, infusion, and oxygenation on the spot for about 20 casualties
2 or 3	Manual or mechanical respirators
2 or 3	Suction devices
300 to 500	Plastic bags for the deceased

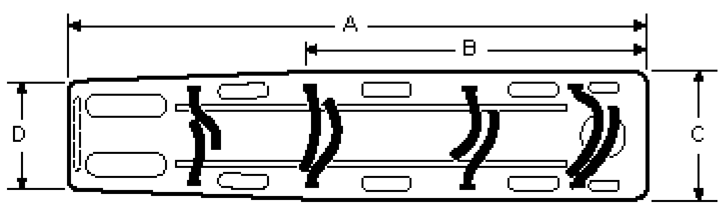
Stretchers, blankets, and backboards or immobilizing mattresses or both should be available for use, preferably on a suitable vehicle (e.g., trailer) that can be transported to the accident site. Blankets are needed to alleviate the casualty's exposure to shock and possible adverse weather conditions. Trauma victims in an aircraft accident sometimes sustain severe spinal injuries, so backboards should be used in removing such casualties from the aircraft in order to minimize the possibility of further spinal injury. The backboards should be of a type designed to fit through access ways and narrow aisles of commercial and business aircraft.

The following material describes some of the items included in Table A-11-1.1(b):

Immobilizing Mattress. This apparatus consists of a plastic bag designed like a mattress and filled with a lot of very small balls. An aspirator (mechanical or other) is used to take out the air so that the mattress is crushed by the atmospheric pressure and becomes as rigid as plaster. A human body, partly enveloped before the mattress is compressed, is completely wrapped and head, limbs, and backbone become immobilized, allowing any type of transportation, through the use of lateral rope loops. The apparatus is permeable to X-rays. Although the dimensions are variable, its length varies generally between 1.80 m and 1.90 m (74 in.) and its width between 0.80 m and 0.90 m (36 in.).

Backboards. These are classified as long and short backboards. The approximate dimensions for a long backboard are shown in Figure A-11-1.1(a). Although a backboard of 1.90 m (74 in.) is shown, some backboards of 1.83 m (72 in.) in length should be available to move through the smallest aircraft emergency exits, 510 mm × 915 mm (20 in. × 36 in.). A 75-mm (3-in.) wide velcro restraining strap is normally required for legs, hips, upper torso, and head.

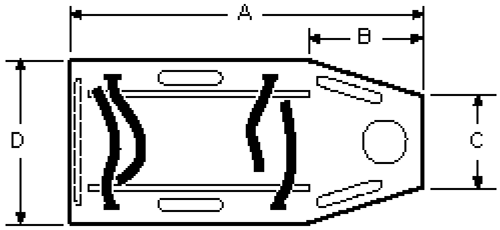
The appropriate dimensions for a short backboard are shown in Figure A-11-1.1(b). A 75-mm (3-in.) wide velcro restraining strap is normally required for lower and upper torso.



A – 1.90 m (74 in.)
B – 1.10 m (43 in.)
C – 0.46 m (18 in.)
D – 0.25 m (10 in.)
Thickness: 19-mm (¾-in.) plywood
Head hole: 140-mm (5-in.) diameter
Hand holes: 250 mm x 50 mm (10 in. x 2 in.)
Foot holes: 250 mm x 75 mm (10 in. x 3 in.)

Note: 25-mm (1-in.) cleats should be placed longitudinally on the underside of the blackboard to facilitate lifting.

Figure A-11-1.1(a) Long backboard.



A – 0.91 m (36 in.)
B – 0.30 m (12 in.)
C – 0.20 m (8 in.)
D – 0.41 m (16 in.)
Thickness: 16-mm (⅝-in.) plywood
Head hole: 114-mm (4-in.) diameter
Hand holes: 150 mm x 38 mm (6 in. x 1 in.)

Note: 25-mm (1-in.) cleats should be placed longitudinally on the underside of the blackboard to facilitate lifting.

Figure A-11-1.1(b) Short backboard.

Miscellaneous Items.

(a) Inflatable tents should have adequate heating and lighting where possible. A large tent can normally accommodate about ten serious cases and can be carried on a large all-purpose vehicle along with the other necessary medical equipment.

(b) Mobile emergency hospitals or inflatable tents, if available [*see Figures A-11-1.1(c), A-11-1.1(d), and A-11-1.1(e)*], or shelters can be used for on-site treatment of Immediate Care (Priority I — Red) and Delayed Care (Priority II — Yellow) casualties. These units should be readily available for rapid response. Planning should also include the assignment of personnel who can operate/assemble this equipment. A cardiac care ambulance unit can be used as an ideal shelter for Immediate Care (Priority I — Red) casualties.

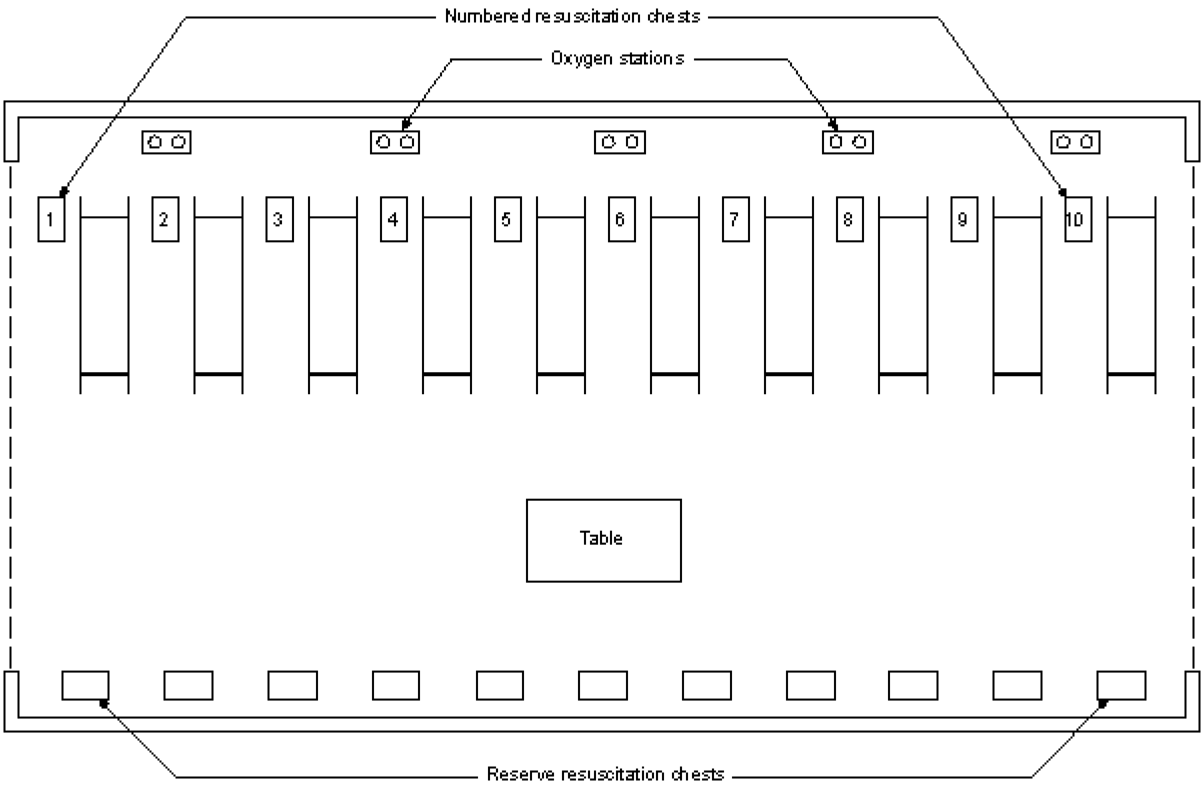


Figure A-11-1.1(c) Schematic of an inflatable tent.

Figure A-11-1.1(d) Containerized hospital emergency mobile.

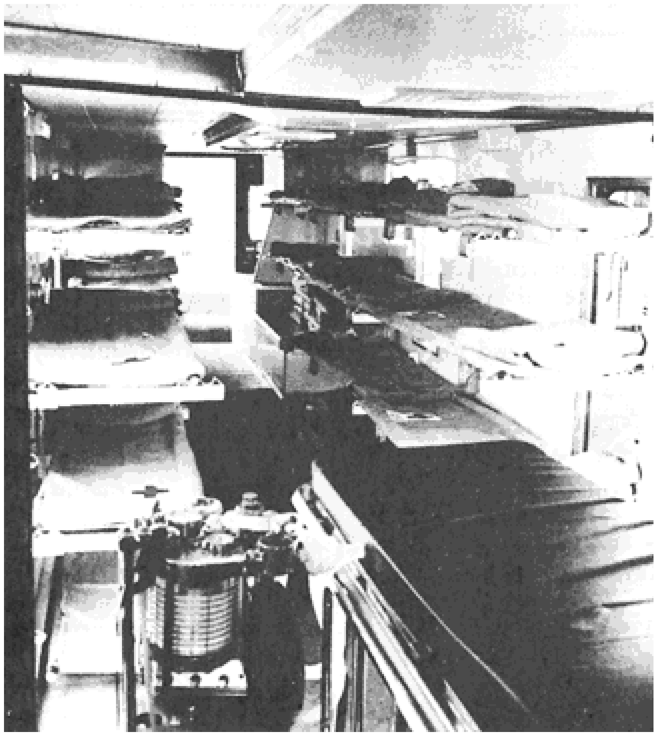


Figure A-11-1.1(e) Interior view of containerized hospital emergency mobile.

Emergency Medical Communication System. Communication is a primary requisite of an airport/community emergency medical plan. The medical service communication system should ensure adequate communication during emergencies to disseminate warning information and obtain support operations. Without communication the hospital cannot know the number and type of casualties it will be receiving, ambulances cannot be directed to the facilities most capable of rendering the needed care, supplies available from outside sources cannot be called for, and medical personnel cannot be directed to the point where they are needed most.

The participating hospitals should have the capability of communicating with one another by means of a two-way radio communication network. Ideally, each hospital should have the capability of either calling other individual hospitals or, if the occasion arises, calling all other hospitals simultaneously. This capability is invaluable for hospitals experiencing an emergency such as a need for a certain blood type or an item of equipment in short supply. It is also recommended that the medical coordinator be able to communicate with participating hospitals directly.

Emergency Medical Transportation Facilities. The dispatch of casualties to hospitals from the accident site should take into consideration the hospital(s) medical personnel on staff, medical specialties, and beds readily available. Ideally, each airport should have available at least one on-call ambulance for routine medical emergencies. Written agreements with off-airport based ambulances should be prepared to provide for emergency transportation services.

In major emergency situations, other means of transportation may be substituted for ambulances. Vans, buses, automobiles, station wagons, or other suitable airport vehicles can be used. Provision for immediate transportation should be available to transport the uninjured or apparently uninjured to a designated holding area.

An area grid map (with date of latest revision) of the airport's surrounding area should be carried by all rescue vehicles. All medical facilities should be depicted prominently on the grid map. (*See Figure A-4-2.2.*)

Assessment of Airport Medical Care Facilities' Needs (Medical Clinic or First Aid Room or Both).

General Factors Influencing Need. There are many general factors that influence the need for an airport first aid room or an airport medical clinic. Factors to be taken into consideration include:

(a) The number of passengers served annually and the number of employees based on the airport;

(b) The industrial activity on the airport property and in the surrounding community;

(c) The distance from adequate medical facilities; and

(d) Mutual aid medical services agreements.

Generally, it is recommended that an airport medical clinic be available when the airport employees number 3000 or more and that a first aid room be available at every airport. The airport medical care or first aid room personnel and facilities should be integrated into the airport/community emergency plan.

The airport medical clinic, in addition to providing emergency medical care to the airport population, can extend emergency care to communities surrounding the airport, if these communities have no emergency facilities of their own.

The airport medical clinic can be included in the community emergency services organization and planning. In the event of a large-scale nonairport local emergency, the airport medical clinic can function as the coordination site for direction of incoming medical personnel assistance as well as medical supplies and equipment.

Location of Airport Medical Care Facilities. The facilities should be readily accessible to the airport terminal building, to the general public, and to emergency transportation equipment (i.e., ambulances, helicopters, etc.). Site selection should avoid the problem of needing to move injured persons through congested areas of the airport terminal building, while providing access to the facility by emergency vehicles. The medical care facility should be located to allow access from the air side of the airport terminal building, as this provides control over unauthorized vehicles interfering with emergency equipment.

Airport Medical Care Facility Personnel. The number of trained personnel and degree of expertise needed by each individual will depend on the particular airport's requirements. The staff of the airport medical clinic should form the nucleus of the medical services planning for the airport/community emergency plan (and be responsible for implementation of the medical portion of the plan). It is recommended that the airport first aid room at least be staffed with highly qualified first aid personnel.

In general it is recommended that during the principal hours of airport activity at least one person trained to deal with the following be available within 3 minutes to 5 minutes:

(a) Cardiopulmonary resuscitation (CPR);

(b) Bleeding from a traumatic source;

(c) Heimlich maneuver (choking);

(d) Fractures and splinting;

(e) Burns;

(f) Shock;

(g) Emergency childbirth and immediate care of newborns, including prematures;

(h) Common medical conditions that can influence the outcome of injury (allergies, high blood pressure, diabetes, pacemaker, etc.);

(i) Basic measures for treatment and protection subsequent to spills or leaks of radioactive materials or toxic or poisonous substances;

(j) Treatment of emotionally disturbed persons;

(k) Recognition of, and first aid for, poisons, bites, and anaphylactic shock; and

(l) Transportation techniques for injured persons.

The person responsible should have authority to order hospitalization if necessary and to arrange any needed transportation.

The airport authority should obtain the advice and direction of a consulting emergency medical care physician as to the allotment and design of equipment for the first aid room commensurate with the anticipated needs of the particular airport.

The equipment and the medical supply inventory of the airport medical clinic should be established by the staff in charge of the clinic.

The airport medical care facility should be equipped to handle cardiac arrest and other types of injuries and illnesses associated with industrial medicine. If drugs are maintained, provision should be made to ensure full security.

Emergency oxygen and respiratory equipment should be available to treat smoke inhalation victims.

Since the majority of nonaccident related medical emergencies at airports involve coronary problems, advance life support systems including oxygen, oxygen regulators, and other elements for cardiopulmonary care should be readily available. In addition, first aid kits (containing drugs, a wide selection of bandages and splints, blood transfusion equipment, and burn and maternity kits), chains, ropes, crowbars, and metal cutters should be available.

A-11-6.6 Casualty Identification Tag. Figures A-11-6.6(a) and A-11-6.6(b) illustrate an example of a casualty identification tag suitable for multilingual applications.

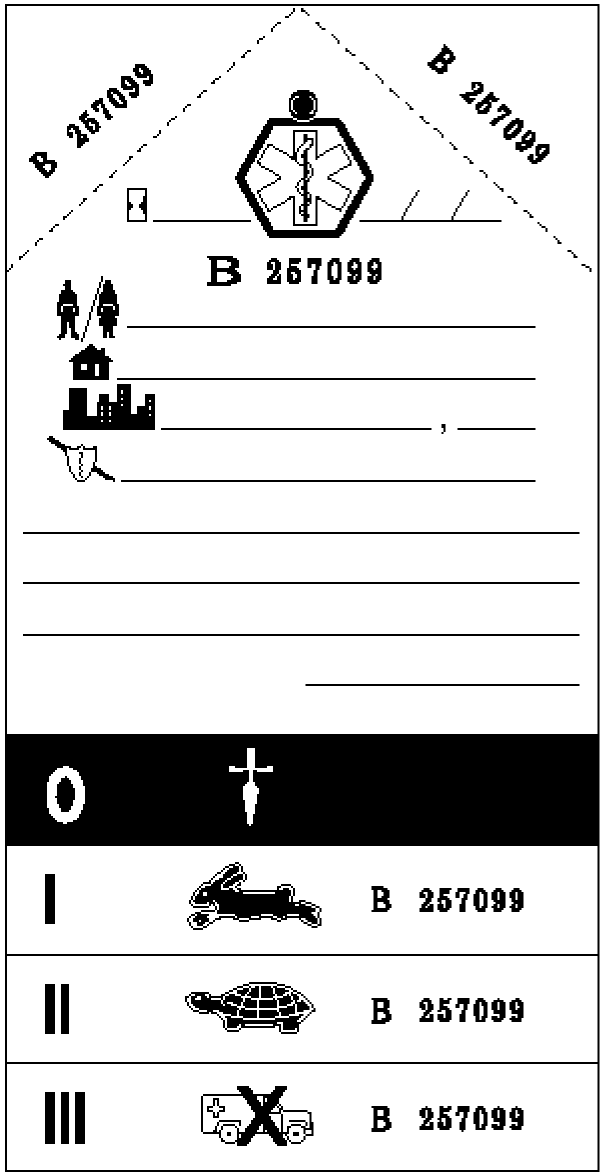


Figure A-11-6.6(a) Casualty identification tag — front.

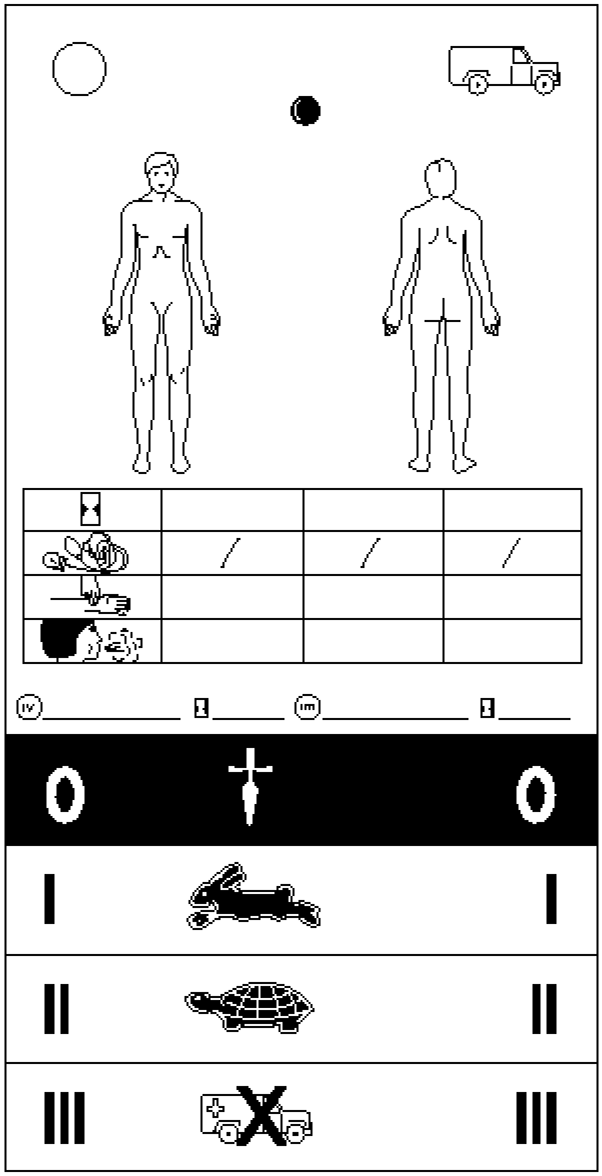


Figure A-11-6.6(b) Casualty identification tag — back.

A-12-1.1 In the United States major aircraft accidents are investigated by the National Transportation Safety Board, 800 Independence Avenue SW, Washington, DC 20591, except those delegated by the Board to the Federal Aviation Administration. Part 430 (Rules Pertaining to Aircraft Accidents, Incidents, Overdue Aircraft, and Safety Investigations) of the National Transportation Safety Board, Section 430.10 reads:

Civil aircraft accident investigation is normally conducted by a number of investigators of the National Transportation Safety Board or their designees interested in establishing the probable cause. Federal or state governments are usually charged with the official responsibility but the operators, pilot groups, airport management, and others may be active in accident investigation work. Fire officials normally make their own investigation.

For guidance on preservation of evidence, see NFPA 402, *Guide for Aircraft Rescue and Fire Fighting Operations*, Section 11-7 and Appendix E.

A-12-2.2 Security measures within the wreckage area should be established as soon as possible. All authorized personnel should have and display proper "Emergency Access" identification as required by the airport/community emergency plan.

All security personnel should be briefed on proper identification procedures. Two-way radio communication with appropriate authorities on the site can help identify any person seeking entry whose credentials are questionable.

Accident sites can be exceptionally dangerous areas, owing to the possible presence of flammable fuels, dangerous goods or hazardous materials, and scattered pieces of wreckage. All necessary safety precautions in the emergency area should be carried out rigidly; this includes exercising good judgment during fire control and throughout all rescue efforts. Safety equipment and approved protective clothing should be worn by all personnel involved. All other personnel should remain outside the security perimeter until the chief fire officer declares the area safe.

A-13-4.2

Emergency Exercise Critique Form
XYZ International Airport

Person performing critique ________________________

General

1. Date and time of emergency ________________________
2. Emergency location ____________________________
3. Type of emergency __________________________

Rescue Operations

Person performing critique ____________________

Organization ______________________

4. Time of emergency notification __________________________
5A. First agency or individual to arrive at emergency ____________________
 B. Time of arrival ______________
6A. Arrival time of airport rescue fire fighting service at emergency ______________________
 B. Approximate number of fire personnel at site ______________
 C. Time and type of first fire protection action (foam, dry chemical, etc.) ________________
7A. Time first casualty evacuated from aircraft________________
 B. How evacuated ______________________
 C. Number of casualties evacuated from inside aircraft________________

D. Time last casualty evacuated from aircraft_________________

Comments: ___________________

8A. Number of injured _____________________

B. Number of noninjured _______________________

C. Number of dead_______________________

9A. Time first casualty transported to triage area ___________________

B. Time last casualty transported to triage area ___________________

10A. Name of other services participating in first aid _________________

B. Who was in charge of these services? _______________

C. How many persons involved? _________________________

11A. Name of other organizations participating in rescue operations___________________________

B. How many persons involved? _________________________

12. Was the moulage realistic? _______________________

Security

Person performing critique _________________________

Organization _________________

13A. Time of emergency notification to police/ security ___________________

B. Who was first police/security officer to arrive at emergency site? _____________________

C. Time of arrival _______________________

14A. How many persons involved?_________________________

B. Did command of security at emergency site change at any time?___________________ If so, give sequence of command change and agency represented

15. Was the traffic satisfactorily controlled? _____________________

16. Was there any provision for the security of personal effects? ___________________

17. Any special problems at accident site with security (spectators, etc.)? ___________________

Medical Services

Person performing critique _______________________

Organization ___________________

18A. Who was first medical official to arrive at emergency site? Medical facility associated with? ___________________

B. Time of notification _______________________

C. How notified? _______________________

D. By whom?________________________
E. Arrival time at emergency site ____________________________
19A. Who was the medical coordinator in charge of medical care and evacuation of casualties? ____________________________
B. Time of notification ________________________
C. How notified? ________________________
D. By whom?__________________________
E. Arrival time at emergency site ________________________________
20A. Number of physicians responding ______________________________
B. Number of nursing personnel responding ___________________
21A. Was a triage area designated at emergency site?___________________
B. Was the triage area located to expedite the flow of casualties?
C. Were the casualties properly classified and tagged? _____________________
D. Were the casualties moved quickly to receiving hospitals? _____________________
22. How were medical and first aid personnel identified? ________________________
23A. What time were relief agencies (Red Cross, Salvation Army, etc.) notified? _____________________
B. How notified? __________________________
C. By whom?____________________________
D. Arrival time ____________________________
E. Personnel participating _________________

Ambulances

Person performing critique ________________________

Organization _____________________
24A. Time of notification to ambulances _____________________
B. How notified? ________________________
C. By whom?__________________________
D. Name of ambulance company ________________________
E. Time of arrival at accident site of first ambulance _____________________
25A. How many casualties did ambulance handle? ___________________
B. Time of departure __________________________
C. Hospital__________________________
D. Arrival time at hospital__________________________
26A. Was ingress or egress to accident site a problem? _________________

Explain: ___________________

B. Any special problems driving from accident site to hospital? _______________

Explain: ____________________

Hospitals

Person performing critique ________________________

Organization ______________________

27. Number of physicians responding______________________
28. Number of nursing personnel responding _________________
29. Number of other hospital personnel responding _________________
30. Number of casualties received ______________________
31. Kind of casualties received ______________________

32A. Time first alert was received ______________________

B. Time disaster message authenticated _________________

C. Time first casualties arrived ________________________

D. Time first casualties were seen by a physician_________________

E. Time last casualties arrived ______________________

F. Time last casualties were seen by a physician_________________

Leadership

Person performing critique ________________________

Organization ____________________

33. Did leadership by incident commander cause people to take effective action?
34. Were there any problems in the coordination of medical, fire, police, and other services? ______________________
35. Was the general spirit of the participants conducive to the success of the exercise? ____________________
36. Who demonstrated leadership? ________________________

Public Information

Person performing critique ________________________

Organization ____________________

37A. Time of notification to airport public information officer _________________

B. How notified? ______________________

C. Arrival time ____________________

38A. Who was the public relations officer? ____________________

B. From what organization? ______________________

39. What special problems were indicated? _________________

Explain: ____________________

Communications and Control

Person performing critique ______________________

Organization __________________

40. Did the command post perform effectively? ______________

41. Did the emergency operations center perform effectively? ______________

42. Was the personnel call system effective?________________

43. Was the physician call system effective?________________

44. Was the emergency message accurately received? ______________

45. Were communications with the hospitals effective? ______________

46. Were there any problems with internal communications? __________________

47. What kinds of communications systems were used? ______________

A. two-way radio ______________________

B. telephone ______________________

C. walkie-talkie ____________________

D. messenger ____________________

E. other ______________________

NARRATIVE: Make any comments that may be helpful in evaluating this exercise ________________

Appendix B Table for International Aircraft Markings

This Appendix is not a part of the recommendations of this NFPA document but is included for informational purposes only.

Table B-1 International Aircraft Markings

A-2-	Botswana	TC-	Turkey
A6-	United Arab Emirates	HA-	Hungary
A7-	Qatar	HB-	Switzerland
A40-	Oman	HB-	Liechtenstein
AP-	Pakistan	HC-	Ecuador
B-	China	HH-	Haiti

C-2-	Nauru	HI-	Dominican Republic
C5-	Gambia	HK-	Colombia
CC-	Chile	HL-	Korea (Rep. of)
CCCP-	U.S.S.R	HP-	Panama
C-, CF-	Canada	HR-	Honduras
CN-	Morocco	HS-	Thailand
CP-	Bolivia	HZ-	Saudi Arabia
CR-, CS-	Portugal	I-	Italy
CU-	Cuba	J2-	Djibouti
CX-	Uruguay	J6-	St. Lucia
D-	Germany (Fed. Rep.)	JA-	Japan
D2-	Angola	JY	Jordan
DQ-	Fiji	LN-	Norway
LV, LQ	Argentina	LX-	Luxembourg
DZ-	Angola	LZ-	Bulgaria
EC-	Spain	N-	U.S.A.
EI-, EJ-	Ireland	OB-	Peru
EL-	Liberia	oD-	Lebanon
EP-	Iran	OE-	Austria
ET-	Ethiopia	OH-	Finland
F-	France	OK-	Czechoslovakia
G-	United Kingdom	ZK-	New Zealand
OO-	Belgium	ZP-	Paraguay
OY-	Denmark	ZS-, ZT-, ZU-	South Africa
P-	North Korea	3A-	Monaco
P2-	Papua New Guinea	3B-	Mauritius
PDRL-	Laos	3C-	Equatorial Guinea
PH-	Netherlands	3D-	Swaziland
PJ-	Netherlands Antilles	3X-	Guinea
PK-	Indonesia	4R-	Sri Lanka
PK-	West Irian	4W-	Yemen
PP-, PT-	Brazil	4X-	Israel

PZ-	Surinam	5A-	Libya
RP-	Philippines	5B-	Cyprus
S-2-	Bangladesh	5H-	Tanzania
SE-	Sweden	5N-	Nigeria
SP-	Poland	5R-	Madagascar
ST-	Sudan	5T-	Mauritania
SU-	Egypt	YU-	Yugoslavia
SX-	Greece	YV-	Venezuela
TF-	Iceland	5U-	Niger
TG-	Guatemala	5V-	Togo
TI-	Costa Rica	5W-	Western Samoa
TJ-	Cameroon	5X-	Uganda
TL-	Central African Rep.	5Y-	Kenya
TN-	Congo	60-	Somalia
TR-	Gabon	6Y-	Jamaica
GV, GW	Senegal	7O-	Democratic Yemen
TS-	Tunisia	7P-	Lesotho
TT-	Chad	7QY-	Malawi
TU-	Ivory Coast	7T-	Algeria
TY-	Benin	8P-	Barbados
TZ-	Mali	8Q-	Maldives
VH-	Australia	8R-	Guyana
VP-, VQ-, VR-	U.K. Colonies & Protectorates	9G-	Ghana
VT-	India	9H-	Malta
XA-, XB-, XC-	Mexico	9J-	Zambia
XT-	Upper Volta	9K-	Kuwait
XU-	Democratic Kampuchea	9L-	Sierra Leone
XV-	Vietnam	9M-	Malaysia
XY-, XZ-	Burma	9N-	Nepal
YA-	Afghanistan	9Q-	Zaire
YI-	Iraq	9U-	Burundi
YK-	Syrian Arab Rep.	9V-	Singapore

YR-	Romania	9XR-	Rwanda
YS-	El Salvador	9Y-	Trinidad and Tobago

Appendix C Recommended Reference Sources

C-1 Recommended Publications. The following documents or portions thereof are recommended within this Appendix for informational purposes only. The edition indicated for each reference is the current edition as of the date of the NFPA issuance of this document.

C-1.1 NFPA Publications. National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.

NFPA 10, *Standard for Portable Fire Extinguishers*, 1994 edition.

NFPA 402, *Guide for Aircraft Rescue and Fire Fighting Operations*, 1996 edition.

NFPA 403, *Standard for Aircraft Rescue and Fire Fighting Services at Airports*, 1993 edition.

NFPA 407, *Standard for Aircraft Fuel Servicing*, 1996 edition.

NFPA 408, *Standard for Aircraft Hand Fire Extinguishers*, 1994 edition.

NFPA 409, *Standard on Aircraft Hangars*, 1995 edition.

NFPA 412, *Standard for Evaluating Aircraft Rescue and Fire Fighting Foam Equipment*, 1993 edition.

NFPA 414, *Standard for Aircraft Rescue and Fire Fighting Vehicles*, 1995 edition.

NFPA 415, *Standard on Aircraft Fueling Ramp Drainage*, 1992 edition.

NFPA 416, *Standard on Construction and Protection of Airport Terminal Buildings*, 1993 edition.

NFPA 417, *Standard on Construction and Protection of Aircraft Loading Walkways*, 1990 edition.

NFPA 418, *Standard for Heliports*, 1995 edition.

NFPA 1001, *Standard for Fire Fighter Professional Qualifications*, 1992 edition.

NFPA 1002, *Standard for Fire Department Vehicle Driver/Operator Professional Qualifications*, 1993 edition.

NFPA 1003, *Standard for Airport Fire Fighter Professional Qualifications*, 1994 edition.

NFPA 1561, *Standard on Fire Department Incident Management System*, 1995 edition.

NFPA 1981, *Standard on Open-Circuit Self-Contained Breathing Apparatus for Fire Fighters*, 1992 edition.

Fire Protection Guide on Hazardous Materials.

C-1.2 Aircraft Rescue and Fire Fighting Manuals.

U.S. Navy *Aircraft Firefighting and Rescue Manual*, NAVAIR 00-80R-14, 1983. (Available from Naval Air Systems Command, Code 1416C, Washington, DC 20360.)

Aircraft Rescue and Fire Fighting (3rd Edition 1992), IFSTA 206. (Available from International Fire Service Training Association, Oklahoma State University, Stillwater, OK 74074.)

Aircraft Emergency Rescue Information, Technical Manual, T.O. 00-105-9. (Available from Hq. NRAMA-MMSTD, Robins Air Force Base, Georgia 31093.)

C-1.3 Aircraft Rescue and Fire Fighting Publications.

AD 739-027, *A Proposed Method for Evaluating Fire Prevention Efforts by the Airport Manager of Non-Hub Airports*, 1970. (Available from National Technical Information Service, Springfield, VA 22151.)

AFAPL-TR-73-74, *Fire and Explosion Manual for Aircraft Accident Investigations*, August 1973, Joseph M. Kuchta, Pittsburgh Mining and Safety Research Center, Bureau of Mines Report No. 4193 published by U.S. Dept. of the Air Force, Air Force Aeoro Propulsion Laboratory, AFAPL/SFH, Wright-Patterson Air Force Base, OH 45433.

C-1.4 Typical ICAO Publications. Available from International Civil Aviation Organization, 1000 Sherbrooke St. W, Montreal, Quebec, Canada H3A 2R2.

International Standards and Recommended Practices — Aerodromes, Annex 14, Second Edition — July 1995.

Airport Services Manual, Part 1, “Rescue and Fire Fighting,” Third Edition, 1990, Doc. 9137-AN/898.

Airport Services Manual, Part 7, “Airport Emergency Planning,” Second Edition, 1991, Doc. 9137-AN/898.

Training Manual, Aerodrome Fire Services Personnel, First Edition, 1976, Doc. 7912-AN/857, Part E-2.

Manual of Aircraft Accident Investigation, Fourth Edition, 1970, Doc. 6920-AN/855/4.

Technical Instructions for the Safe Transport of Dangerous Goods by Air, 1995-1996.

C-1.5 Air Line Pilots Association. ALPA *Guide for Airport Standards*, First Edition, July 1969, Third Edition, 1981. (Available from Air Line Pilots Association, Engineering and Air Safety Department, 535 Herndon Parkway, Herndon, VA 22070.)

C-1.6 Federal Aviation Administration Publications. Send your order to:

U.S. Department of Transportation
Subsequent Distribution Office
Ardmore East Business Center
3341 Q 75th Ave.
Landover, MD 20785.

Advisory Circulars. This listing is limited to advisory circulars of substance concerning aircraft rescue and fire fighting. For a complete listing of FAA advisory circulars, write the FAA and request a copy of the latest “Advisory Circular Checklist.” This checklist is published periodically in the *Federal Register*. This listing of advisory circulars is as of April 2, 1985.

150/5200-12A, *Fire Department Responsibility in Protecting Evidence at the Scene of an Aircraft Accident* (4-8-85). (AAS-100). Furnishes general guidance for airport, employees, airport management and other personnel responsible for fire fighting and rescue operations, at the scene of an aircraft accident, on the proper presentation of evidence.

150/5200-18B, *Airport Safety Self-Inspection* (5-2-88). (AAS-310). Provides information to airport operators on airport self-inspection programs and identifies items that should be included in such a program.

150/5210-2A, *Airport Emergency Medical Facilities and Services* (11-27-84). (AAS-300). Provides information and advice so that airports may take specific voluntary pre-planning actions to assure at least minimum first-aid and medical readiness appropriate to the size of the airport in terms of permanent and transient personnel.

150/5210-5B, *Painting, Marking, and Lighting of Vehicles Used on an Airport* (7-11-86). (AAS-120). Provides guidance, specifications, and standards, in the interest of airport personnel safety and operational efficiency, for painting, marking, and lighting of vehicles operating in the airport air operations areas.

150/5210-6C, *Aircraft Fire and Rescue Facilities and Extinguishing Agents* (1-28-85). Outlines scales of protection considered as the recommended level compared with the minimum level in FAR Part 139.49 and tells how these levels were established.

150/5210-7B, *Aircraft Fire and Rescue Communications* (4-30-84). Provides airport management with information helpful in the establishment of communication and alarm facilities. Such facilities alert and guide those personnel who must deal with aircraft ground emergencies.

150/5210-13A, *Water Rescue Plans, Facilities, and Equipment* (5-31-91). (AAS-120). Provides guidance to assist airport operators in preparing for water rescue operations.

150/5220-4B, *Water Supply Systems for Aircraft Fire and Rescue Protection* (7-29-92). (AAS-120). Provides guidance for the selection of a water source and standards for the design of a distribution system to support aircraft rescue and firefighting (ARFF) service operations on airports.

150/5220-10A, *Guide Specification for Water/Foam Aircraft Rescue and Firefighting Vehicles* (7-3-91). (AAS-120). Contains performance standards, specifications, and recommendations for the design, construction, and testing of a family of aircraft rescue and firefighting (ARFF) vehicles.

150/5230-4, *Aircraft Fuel Storage, Handling, and Dispensing On Airports* (8-27-82). (AAS-300). (Consolidated reprint includes changes 1 and 2). Provides information on aviation fuel deliveries to airport storage and the handling, cleaning, and dispensing of fuel into aircraft.

150/5370-2C, *Operational Safety On Airports During Construction* (5-31-84). (AAS-300). Concerning operational safety on airports with special emphasis on safety during periods of construction activity, to assist airport operators in complying with Part 139.

139.49-1, *Programs for Training of Fire Fighting and Rescue Personnel* (11-12-74). Suggested training programs for airport fire fighting and rescue personnel.

C-1.7 ASTM Standard. This publication makes reference to the following ASTM standard, and the year date indicates the latest edition available. It is available from the American Society for Testing and Materials, 1916 Race Street, Philadelphia, Pennsylvania 19103.

ASTM E 380, *Standard for Metric Practice*, 1993.

C-1.8 Federal Aviation Regulations.

Part 139, *Certification and Operations: Land Airports Serving Certain Air Carriers*, January 1988. Sold on a subscription basis by the Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402.

C-1.9 U.S. Air Force Technical Reports.

AGFSRS 71-3, Accident/Incident Survey Data Analysis for Aircraft Ground Fire Suppression and Rescue Systems — UDRI, October 1971.

C-1.10 U.S. Government Publications.

Code of Federal Regulations, U.S. Government Printing Office, Washington, DC 20402.

DOD-AGFSRS-75-5, *Aircraft Ground Fire Suppression and Rescue Simulation Model — UD*, August 1975.

DOD-AGFSRS-76-2, *A Study to Evaluate the Intensity of and Alternative Methods for Neutralization of DOF Aircraft Fuel Spills; Phase 1 USA MERDC*, February 1976.

NOTE: Full size or microfiche copies of the DOD listed reports are available directly from the National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161.

Emergency Medical Services Communications Systems, U.S. Department of Health, Education & Welfare. Health Services and Mental Health Administration Division of Emergency Health Services, 5000 Fishers Lane, Rockville, MD 20852.

DHEN Publication No. (HSM) 73-2003

What to Do and How to Report Military Aircraft Accidents, U.S. Naval Aviation Safety Center, U.S. Naval Air Station, Norfolk, VA 23511.

National Transportation Safety Board, *Civil Aircraft Accident Investigation Guidelines*, Washington, DC 20591.

C-2 Organizations. The following list provides the addresses of organizations throughout the world that may serve as useful sources of information and assistance.

C-2.1 National Operations.

Aircraft Owners and Pilots Association (AOPA), 421 Aviation Way, Frederick, MD 21701; phone: (301) 695-2000; fax: (301) 695-2375; cable address: AOPA, Washington, DC. Offices open Monday through Friday, 8:30–5:00 (EST).

Department of Transportation
400 Seventh Street, S.W.
Washington, DC 20590
Federal Aviation Administration
800 Independence Avenue, S.W.
Washington, DC 20591
Phone: (202) 366-3282

Domestic FAA Regional Offices:

Alaskan Region — Anchorage Governing Alaska and Aleutian Islands
Airports Division, AAL-600
Federal Aviation Administration

Anchorage Federal Office Building
222 West 7th Avenue, Box 14
Anchorage, AK 99513

Central Region — Kansas City Governing Iowa, Kansas, Missouri, Nebraska
Airports Division, ACE-600
Federal Aviation Administration
Federal Building
601 East 12th Street
Kansas City, MO 64106

Eastern Region — New York Governing Delaware, District of Columbia, Maryland, New Jersey, New York, Pennsylvania, Virginia, West Virginia
John F. Kennedy Int'l Airport
Airports Division, AEA-600
Federal Aviation Administration
Fitzgerald Federal Building, Rm. 329
Jamaica, NY 11430
Duty hours 8:00–4:30 EST (DST from last Sunday in
April through last Sunday in October)

Great Lakes Region — Chicago Governing Illinois, Indiana, Minnesota, Michigan, Ohio, Wisconsin, North and South Dakota
Airports Division, AGL-600
Federal Aviation Administration
2300 E. Devon Avenue
Des Plaines, IL 60018

New England Region — Boston Governing Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, Vermont
Airports Division, ANE-600
Federal Aviation Administration
12 New England Executive Park
Burlington, MA 01803

Northwest Mountain Region — Seattle Governing Idaho, Oregon, Washington, Colorado, Montana, Utah, Wyoming
Airport Division, ANM-600
Federal Aviation Administration
1601 Lind Avenue, S.W.
Renton, WA 98055-4056

Southern Region — Atlanta Governing Alabama, Florida, Georgia, Mississippi, North Carolina, South Carolina, Tennessee, Kentucky, Puerto Rico, U.S. Virgin Islands
Airports Division, ASO-600
Federal Aviation Administration
1701 Columbia Avenue
College Park, GA 30337

Mail Address:
Airports Division, ASO-600

Federal Aviation Administration
1 P.O. Box 20636
Atlanta, GA 30320

Southwest Region — Fort Worth Governing Arkansas, Louisiana, New Mexico, Oklahoma, Texas

Airports Division, ASW-600
Federal Aviation Administration
2601 Meacham Boulevard
Fort Worth, TX 76173-4298

Mail Address:
Department of Transportation, ASW-600
Federal Aviation Administration
Forth Worth, TX 76193-0600

Western Pacific Region — Los Angeles Governing Arizona, California, Nevada, Hawaii, Western Pacific

Airports Division, AWP-600
Federal Aviation Administration
15000 Aviation Boulevard
Lawndale, CA 90261

Mail Address:
Airports Division, AWP-600
Federal Aviation Administration
P.O. Box 92007
Worldway Postal Center
Los Angeles, CA 90009

FAA General Aviation District Offices: (Unless otherwise noted, address correspondence to General Aviation District Office, Federal Aviation Administration.)

Alaskan Region
Airports Division, AAL-600
Federal Aviation Administration
Anchorage Federal Office Building
222 West 7th Avenue, Box 14
Anchorage, AK 99513

Central Region
Airports Division, ACE-600
Federal Aviation Administration
Federal Building
601 East 12th Street
Kansas City, MO 64106

Eastern Region
Pennsylvania, Delaware

Airports District Office, HAR-ADO
Federal Aviation Administration

3911 Hartsdale Drive, Suite 1
Camp Hill, PA 17011

Maryland, Virginia, District of Columbia
Airports District Office, WASH-ADO
Federal Aviation Administration
101 W. Broad Street, Suite 300
Falls Church, VA 22046

West Virginia
Airports Field Office, BKW-AFO
Federal Aviation Administration
Main Terminal Building, Room 101
469 Airport Circle
Beaver, WV 25813-9759

Great Lakes Region
Illinois, Indiana
Airports District Office, CHI-ADO-600
Federal Aviation Administration
2300 East Devon Avenue
Des Plaines, IL 60018

Ohio, Michigan
Airports District Office, DET-ADO-600
Federal Aviation Administration
8820 Beck Road
East Willow Run Airport
Belleville, MI 48111

Wisconsin, Minnesota, South Dakota
Airports District Office, MSP-ADO-600
Federal Aviation Administration
6020 28th Avenue, South
Minneapolis, MN 55450

North Dakota
Airports Field Office, BIS-AFO
Federal Aviation Administration
2000 University Drive
Bismarck, ND 58504

New England Region
Airports Division, ANE-600
Federal Aviation Administration
12 New England Executive Park
Burlington, MA 01803

Northwest Mountain Region
Washington, Oregon, Idaho
Airports District Office, SEA-ADO

Federal Aviation Administration
1601 Lind Avenue, S.W.
Renton, WA 98055-4056

Colorado, Wyoming, Utah
Airports District Office, DEN-ADO
Federal Aviation Administration
5440 Roslyn, Suite 300
Denver, CO 80216-6026

Montana
Airports District Office, HLN-ADO
Federal Aviation Administration
FAA Building, Room 2
Helena Regional Airport
Helena, MT 59601

Southern Region
Georgia, North Carolina, South Carolina
Airports District Office, ATL-ADO
Federal Aviation Administration
Campus Building
1701 Columbia Avenue, Suite 2-260
College Park, GA 30337-2747

Florida, Puerto Rico, Virgin Islands
Airports District Office, ORL-ADO
Federal Aviation Administration
9677 Tradeport Drive, Suite 130
Orlando, FL 32827

Tennessee, Kentucky
Airports District Office, MEM-ADO
Federal Aviation Administration
2851 Directors Cove, Suite 3
Memphis, TN 38131-0301

Mississippi, Alabama
Airports District Office, JAN-ADO
Federal Aviation Administration
FAA Bldg. Jackson International Airport
120 N. Hangar Drive, Suite B
Jackson, MS 39208-2306

Southwest Region
Arkansas, Louisiana
Airport Development Office, ASW-630
Department of Transportation
Federal Aviation Administration
Fort Worth, TX 76193-0630

Texas

Airport Development Office, ASW-650
Department of Transportation
Federal Aviation Administration
Fort Worth, TX 76193-0650

New Mexico, Oklahoma
Airport Development Office, ASW-640
Department of Transportation
Federal Aviation Administration
Fort Worth, TX 76193-0640

Oklahoma City Airports District Office
Federal Aviation Administration
5909 Phillip J. Rhodes Avenue
Wiley Post Airport
Bethany, OK 73008

Albuquerque Airports District Office
Federal Aviation Administration
1601 Randolph SE, Suite 201N
Albuquerque, NM 87106

Western-Pacific Region
Northern California,[1] Nevada
Airports District Office, SFO-600
Federal Aviation Administration
831 Mitten Road, Room 210
Burlingame, CA 94010-1303
Hawaii, Trust Territory of the Pacific Islands, American Samoa, Guam, and Commonwealth of Northern Marianas Islands
Airports District Office, HNL-600
Federal Aviation Administration
Prince Jonah Kuhio Kalanianaole Bldg.
300 Ala Moana Boulevard, Room 7116
Honolulu, HI 96813

Mail Address:
Airports District Office, HNL-600
Federal Aviation Administration
Box 50244
Honolulu, HI 96850-0001

[1]Northern California includes the counties of San Luis Obispo, Kings, Tulare, Fresno, Mono, and all counties north thereof. Southern California includes the counties of Santa Barbara, Kern, Inyo, and all counties south thereof, which are served directly from the Airports Division, AWP-600.

C-2.2 Federal Communications Commission, 1919 M St., N.W., Washington, DC 20554. Consumer Assistance and Small Business Division; phone (202) 418-0200.

FCC Field Operating Offices

Anchorage, AK — Federal Building & U.S. Courthouse, P.O. Box 2955, 1011 East Tudor Rd., Room 240, Anchorage, AK 99510

Atlanta, GA — Room 440, Massell Building, 1365 Peachtree St., N.E., Atlanta, GA 30309

Baltimore, MD — 1017 Federal Building, 31 Hopkins Plaza, Baltimore, MD 21201

Boston, MA — 1600 Customhouse, 165 State Street, Boston, MA 02109

Buffalo, NY — 1307 Federal Building, 111 West Huron St., Buffalo, NY 14202

Chicago, IL — 230 S. Dearborn St., Room 3940, Chicago, IL 60604

Cincinnati, OH — 8620 Winton Rd., Cincinnati, OH 45231

Dallas, TX — Earle Cabell Federal Building, U.S. Courthouse, Room 13E7, 1100 Commerce St., Dallas, TX 75242

Denver, CO — 12477 West Cedar Dr., Denver, CO 80228

Detroit, MI — 1054 Federal Building, 231 W. LaFayette St., Detroit, MI 48226

Honolulu, HI — Prince Kuhio Federal Building, 300 Ala Moana Blvd., Room 7304, P.O. Box 50023, Honolulu, HI 96850

Houston, TX — New Federal Office Building, 515 Rusk Ave., Room 5636, Houston, TX 77002

Kansas City, MO — Brywood Office Tower, Room 320, 8800 East 63rd St., Kansas City, MO 64133

Long Beach, CA — Room 501, 3711 Long Beach Blvd., Long Beach, CA 90807

Miami, FL — Room 919, 51 S.W. First Ave., Miami, FL 33130

New Orleans, LA — 1009 F. Edward Hebert Federal Building, 600 South St., New Orleans, LA 70130

New York, NY — 2-1 Varick St., New York, NY 10014

Norfolk, VA — Military Circle, 870 N. Military Highway, Norfolk, VA 23501

Philadelphia, PA — One Oxford Valley Office Bldg., Suite 505, 2300 E. Lincoln Highway, Langhorne, PA 19047

Portland, OR — 1782 Federal Office Building, 1220 S.W. Third Ave, Portland, OR 97204

St. Paul, MN — 691 Federal Building & U.S. Courthouse, 316 North Robert St., St. Paul, MN 55101

San Diego, CA — 7840 El Cajon Blvd., Room 405, La Mesa, CA 92041

San Francisco, CA — 423 Customhouse, 555 Battery St., San Francisco, CA 94111

San Juan, Puerto Rico — 747 Fed eral Building, Hato Rey, Puerto Rico, 00918

Seattle, WA — 3256 Federal Building, 915 Second Ave., Seattle, WA 98174

Tampa, FL — Interstate Bldg., Room 601, 1211 N. Westshore Blvd., Tampa, FL 33607

C-2.3 National Transportation Safety Board, 800 Independence Ave., S.W., Washington, DC 20594. Phone (202) 382-6600.

NTSB Field Offices

Northeast Regional Office, 2001 Route 46, Suite 203, Parsippany, NJ 07054

Northeast Field Office, 490 L'Enfant Plaza, S.W., Washington, DC 20594

Southeast Regional Office, 8405 N.W. 53rd Street, Suite B-103, Miami, FL 33166

Southeast Field Office, 1720 Peachtree Street, N.W., Suite 321, Atlanta, GA 30309

North Central Regional Office, 31 West 775 North Avenue, West Chicago, IL 60185

South Central Regional Office, 1200 Copeland Road, Suite 300, Arlington, TX 76011

South Central Field Office, 4760 Oakland Street, Suite 500, Denver, CO 80239

Northwest Regional Office, 19518, Pacific Highway South, Room 201, Seattle, WA 98188

Northwest Field Office, 222 West 7th Avenue, Room 142, Box 11, Anchorage, AK 99513

Southwest Regional Office, 1515 W. 190th Street, Suite 555, Gardena, CA 90248

State Aeronautical Agencies

Alabama Dept. of Aeronautics, State Highway Bldg., 11 S. Union St., Montgomery, AL 36130

Alaska Dept. of Transportation and Public Facilities, Commissioner of Transportation, Pouch Z, Juneau, AK 99811, or Pouch 6900, Anchorage, AK 99502

Arizona Div. of Aeronautics, 1801 W. Jefferson, Room 426, Phoenix, AZ 85007

Arkansas Div. of Aeronautics, Adams Field — Old Terminal Bldg., Little Rock, AR 72202

California Div. of Aeronautics, Dept. of Transportation, 1120 N St., Sacramento, CA 95814

Colorado, Office of the Governor, 136 State Capital Bldg., Denver, CO 80203 (There is no state aviation agency.)

Connecticut Bureau of Aeronautics — DOT, P.O. Drawer A 24 Wolcott Hill Rd., Wethersfield, CT 06109

Delaware Transportation Authority, Dept. of Transportation, P.O. Box 778, Dover, DE 19901

Florida Bureau of Aviation, Dept. of Transportation, P.O. Box 778, Dover, DE 19901

Georgia Bureau of Aeronautics, Dept. of Transportation, 5025 New Peachtree Rd., N.E., Chamblee, GA 30341

Hawaii Airports Division, Dept. of Transportation, Honolulu International Airport, Honolulu, HI 96819

Idaho Div. of Aeronautics and Public Transportation, 3483 Rickenbacker St., Boise, ID 83705

Illinois Div. of Aeronautics, Dept. of Transportation, Capital Airport — One Langhorne Bond Dr., Springfield, IL 62706

Indiana Div. of Aeronautics, 143 West Market St., Suite 300, Indianapolis, IN 46204

Iowa Aeronautics Div., Dept. of Transportation, State House, Des Moines, IA 50319

Kansas Aviation Div., Dept. of Transportation, State Office Bldg., Topeka, KS 66612

Kentucky Div. of Mass Transportation, Dept. of Transportation, State Office Bldg., Frankfort, KY 40622

Louisiana Office of Aviation and Public Transportation, Dept. of Transportation and Development, P.O. Box 44245 Capitol Station, Baton Rouge, LA 70804

Maine Division of Aeronautics, Dept. of Transportation, State Office Bldg., Augusta, ME 04333

Maryland State Aviation Administration, Dept. of Transportation, P.O. Box 8766, Baltimore-Washington International Airport, Baltimore, MD l21240

Massachusetts Aeronautics Commission, Boston-Logan Airport, E. Boston, MA 02128

Michigan Aeronautics Commission, Dept. of Transportation, Capital City Airport, Lansing, MI 48906

Minnesota Aeronautics Division, Department of Transportation, Transportation Bldg., St. Paul, MN 55155

Mississippi Aeronautics Commission, P.O. Box 5, 500 Robert E. Lee Bldg., Jackson, MS 39205

Missouri Aviation Division, Aviation Unit, P.O. Box 270, Jefferson City, MO 65102

Montana Aeronautics Division, Department of Commerce, P.O. Box 5178, Helena, MT 59604

Nebraska Dept. of Aeronautics, P.O. Box 82088, Lincoln, NE 68501

Nevada Office of the Governor, The State of Nevada, Carson City, NV 89710 (There is no state aviation agency.)

New Hampshire Aeronautics Commission, Municipal Airport, Concord, NH 03301

New Jersey Div. of Aeronautics, Dept. of Transportation, 1035 Parkway Ave., Trenton, NJ 08625

New Mexico Aviation Div., Dept. of Transportation, P.O. Box 579, Santa Fe, NM 87503

New York Aviation Bureau, Dept. of Transportation, 1220 Washington Ave., Albany, NY 12232

North Carolina Div. of Aviation, Dept. of Transportation, P.O. Box 25201, Raleigh, NC 27611

North Dakota Aeronautics Commission, Box 5020 Bismarck Airport, Bismarck, ND 58502

Ohio Div. of Aviation, 2829 W. Granville Rd., Worthington, OH 43085

Oklahoma Aeronautics Commission, 424 United Founders Tower, Oklahoma City, OK 73112

Oregon Div. of Aeronautics, Dept. of Transportation, 3040-25th St., S.E., Salem, OR 97310

Pennsylvania Bureau of Aviation, Dept. of Transportation, 45 Luke Drive, Harrisburg Int’l Airport, Middletown, PA 17057

Puerto Rico Ports Authority, GPO Box 2829, San Juan, P.R. 00936

Rhode Island Div. of Airports, Dept. of Transportation, Theodore Francis Green State Airport, Warwick, RI 02886

South Carolina Aeronautics Commission, Drawer 1987, Columbia Metropolitan Airport, Columbia, SC 29202

South Dakota Div. of Aeronautics, Dept. of Transportation, Transportation Bldg., Pierre, SD 57501

Tennessee Office of Aeronautics, Dept. of Transportation, P.O. Box 17326, Nashville Metropolitan Airport, Nashville, TN 37217

Texas Aeronautics Commission, P.O. Box 12607, Capitol Station, Austin, TX 78711

Utah Aeronautical Operations Div., Dept. of Transportation, 135 North 2400 West, Salt Lake City, UT 84116

Vermont Agency of Transportation, Aeronautics Operations, State Administration Bldg., Montpelier, VT 05602

Virginia Dept. of Aviation, P.O. Box 7716, 4508 S. Laburnum Ave., Richmond, VA 23231

Washington Div. of Aeronautics, Dept. of Transportation, 8600 Perimeter Rd., Boeing Field, Seattle, WA 93108

West Virginia Aeronautics Commission, Kanawha Airport, Charleston, WV 25311

Wisconsin Bureau of Aeronautics, Dept. of Transportation, P.O. Box 7914, Madison, WI 53707

Wyoming Aeronautics Commission, Cheyenne, WY 82002

C-2.4 Aviation Organizations.

Aeronautical Radio, Inc. (ARINC), 2551 Riva Rd., Annapolis, MD, 21401 Aerospace Industries Association of America, Inc., 1725 De Sales St., N.W., Washington, DC 20036

Aerospace Medical Association, Washington National Airport, Washington, DC 20001

Airborne Law Enforcement Association, Inc., 716 N. 21st St., Birmingham, AL 35263

Air Force Association, 1750 Pennsylvania Ave., N.W., Suite 400, Washington, DC 20006

Air Line Pilots Association (ALPA), 1625 Massachusetts Ave., N.W., Washington, DC 20036

Airport Operators Council, International (AOCI) 1220 19th St., N.W., Suite 800, Washington, DC 20036

Air Transport Association of America (ATA), 1709 New York Ave., N.W., Washington, DC 20006

Allied Pilots Association, 2621 Ave. “E” East, Suite 208, Arlington, TX, 76011 American Association of Airport Executives, 2029 K St., N.W., Washington, DC 20006

American Helicopter Society, Inc., 217 N. Washington St., Alexandria, VA

American Society for Aerospace Education, 1750 Pennsylvania Avenue, N.W., Suite 1303, Washington, DC 20006

Animal Air Transportation Association, 6180 S.W. 56th Ct., Davie, FL 33314

Antique Airplane Association, Rt. 2, Box 172, Ottumwa, IA 51501

Association of Aviation Psychologists, 6955 Snowbird Dr., Colorado Springs, CO 80918

Aviation Distributors and Manufacturers Association (ADMA), 1900 Arch St., Philadelphia, PA 19103

Aviation Maintenance Foundation, P.O. Box 739, Basin, WY 82410

Aviation/Space Writers Association, Cliffwood Rd., Chester, NJ 07930

Civil Aeronautics Board, 1825 Connecticut Ave., N.W., Washington, DC 20428

Civil Air Patrol, Headquarters, Maxwell Air Force Base, AL 36112; Attn: DO

Civil Aviation Medical Association, 801 Green Bay Rd., Lake Bluff, IL 60044

Commuter Airline Association of America, 1101 Connecticut Ave., N.W., Suite 700, Washington, DC 20036

Confederate Air Force, Rebel Field, P.O. Box CAF, Harlington, TX 78551

Experimental Aircraft Association, Inc. (EAA), P.O. Box 229, Hales Corners, WI 53130

Flight Safety Foundation, Inc., 5510 Columbia Pike, Arlington, VA 22204

General Aviation Manufacturers Association (GAMA), 1400 K St., N.W., Suite 801, Washington, DC 20005

Helicopter Association International, 1110 Vermont Ave., N.W., Suite 430, Washington, DC 20005

International Airline Passengers Association, P.O. Box 22074, Dallas, TX 75222

International Aviation Theft Bureau, 7315 Wisconsin Ave., Bethesda, MD 20814

National Aeronautic Association (NAA) 821 15th St., N.W., Suite 430, Washington, DC 20005

National Air Transportation Association, Inc., 1010 Wisc. Ave., N.W., Suite 405, Washington, DC 20007

National Association of Air Traffic Specialists, Wheaton Plaza North Bldg., Suite 415, Wheaton, MD 20902

National Association of Flight Instructors (NAFI), Ohio State University Airport, Box 20204, Columbus, OH 43220

National Association of State Aviation Officials (NASAO), 1300 G St., N.W., Washington, DC 20005

National Business Aircraft Association, Inc. (NBAA), One Farragut Square South, Washington, DC 20006

National Intercollegiate Flying Association (NIFA), 4627 Ocean Blvd., #220, San Diego, CA 92109

(The) Ninety-Nines, Inc. (international organization of women pilots), Will Rogers World Airport, Oklahoma City, OK 73159

Society of Automotive Engineers, Inc., 400 Commonwealth Dr., Warrendale, PA 15096

Society of Flight Test Engineers, Inc., P.O. Box 4047, Lancaster, CA 93539

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C-2.5 IAOPA Member Organizations.

International Council of Aircraft Owner and Pilot Associations (IAOPA), Headquarters, 7315 Wisconsin Ave., Bethesda, MD 20814.

IAOPA European Branch Office, P.O. Box 55, 2110 AB Aerdenhout, Netherlands. Cable address: GENERAVIA AERDENHOUT NETHERLANDS.

AOPA Australia, Box 2912, G.P.O., Sydney, 2001, Australia; cables: same as mailing address

AOPA Austria, Postfach 114, Vienna A-1171, Austria; Telex: 74914

AOPA Belgium, Fraithobann 107/B.73 2600 Berchem, Antwerp, Belgium

Associacao de Pilotos, Proprieterior de Aeronaves, Caixa Postal 19.009, Sao Paulo, Brazil

Canadian Owners and Pilots Association, P.O. Box 734, Station B, Ottawa, Ontario, KIP 5S4 Canada; Telex 053-4286; cables: same as mailing address

Asociacion Colombiana de Aviacion Civil General, Apartado Aereo No. 59656, Bogota, D.E., Colombia; cables: AVIACION GENERAL

AOPA Denmark, Box 52, DK 4930 Maribo, Denmark

Association des Pilotes Prives, Bureau No. 10, Batiment Paul-Bert, 93350 Aeroport le Bourget, France; cables: same as mailing address

AOPA Germany, Haus Nr. 1, 6073 Egelsback/Flugplatz, Germany; Telex 4150 23

Aeroclub de Guatemala, Aeropuerto La Aurora, Apartado Postal 672, Guatemala

AOPA Ireland, P.O. Box 927, Nassau St., Dublin 2, Ireland

Israeli Association of General Aviation, Herzlia Airport, P.O. Box 3034, Herzlia Bet, Israel

AOPA Italy, Via G. Schiavoni, 4, 20142 Milan, Italy

Japan Aircraft Owner-Pilot Association, c/o Koyo Building, 4th Floor, 7-9, 1-Chome, Sendagaya, Shibuya-ku, Tokyo 151, Japan

Union des Pilotes d'Aviation du Grande-Duche de Luxembourg, P.O. Box 675, G.D. of Luxembourge; cables: same as mailing address

AOPA Netherlands, Dorpshuisstraat 10, 9663 GG Nieuwe Pekela, Netherlands; cables: same as mailing address

Nigeria Aircraft Owners and Pilots Association, P.O. Box 4134, Ikeja, Lagos, Nigeria

AOPA Norway, P.O. Box 1604, Vika, Oslo 1, Norway

AOPA Philippines, P.O. Box 7070, Manila International Airport 3120, Philippines; cables: same as mailing address

AOPA South Africa, P.O. Box 1789, Pretoria 0001, Republic of South Africa; Telex: 3-524 SA

AOPA Spain, Mallorca 264/3/2, Barcelona 9, Spain; 52876 bsp e

AOPA Sweden, Box 10014, S-161, 10 Bromma, Sweden; cables: same as mailing address. Telex: 10725 FFA S

AOPA Switzerland, P.O. Box 113, 8302 Kloten, Switzerland; cables: AOPASWISS ZURICH

AOPA U.K., 50 Cambridge Street, London, SWIC 4QQ, England; cables: AVIACENTRE LONDON; Telex: 262284, Ref. 2290

Aircraft Owners and Pilots Association, 7315 Wisconsin Ave., Bethesda, MD 20814, U.S.A.

Federacion Venezolona de Aeroclubes, Base Aerea F. de Miranda, Carlota, Apartado de Correo 5372, Caracas, Venezuela; cables: same as mailing address

C-2.6 FAA International Offices. Europe, Africa, Middle East Headquarters.

FAA, Brussels, Belgium — Director, c/o American Embassy, APO New York, NY 09667. Location/International Mail Address: FAA, c/o American Embassy, 15, rue de la Loi, 1040

Brussels, Belgium.

NFPA 430

1995 Edition

Code for the Storage of Liquid and Solid Oxidizers

1995 Edition

This edition of NFPA 430, *Code for the Storage of Liquid and Solid Oxidizers*, was prepared by the Technical Committee on Hazardous Chemicals, and acted on by the National Fire Protection Association, Inc., at its Annual Meeting held May 22-25, 1995, in Denver, CO. It was issued by the Standards Council on July 21, 1995, with an effective date of August 11, 1995, and supersedes all previous editions.

This edition of NFPA 430 was approved as an American National Standard on August 11, 1995.

Origin and Development of NFPA 430

At the 1969 NFPA Annual Meeting, the Sectional Committee on Storage, Handling and Transportation of Hazardous Chemicals obtained tentative adoption of a *Code for the Storage and Transportation of Oxidizing Materials and Organic Peroxides*, No. 499-T. Subsequently, the Sectional Committee decided to replace No. 499-T with two codes, one for the storage of liquid and solid oxidizers and the other for organic peroxides.

The text printed here contains those requirements that the Sectional Committee believes to be essential for the safe storage of liquid and solid oxidizers. It was processed in accordance with the NFPA Regulations Governing Committee Projects. A draft was adopted as a Tentative Code in 1971. In 1972, an amended version of the 1971 edition was adopted as a Tentative Code. The 1972 edition, with further revisions, was officially adopted by the Association in 1973, Amendments were adopted in 1974, 1975, and 1980.

For the 1990 edition of NFPA 43A, the Committee initiated a complete revision of the document that incorporates revised limits for the quantities of oxidizers stored in buildings, whether they are sprinklered or nonsprinklered. The limits were revised in consideration of the burning characteristics and loss experience this class of chemicals has demonstrated over the past few years. In this edition, the Committee has provided enhanced requirements for the storage of oxidizers in retail establishments. The Committee also included an enhanced list of typical oxidizers covered by this code in the appendix as a guide to users of the document.

This 1995 edition of NFPA 430 consists of a renumbering of the former code NFPA 43A. It represents a complete revision of the document to update the requirements for the safe handling, fire prevention, and storage provisions for liquid and solid oxidizers. This edition incorporates new material into the document to reflect changes in protection technology, particularly in the requirements for sprinkler protection of oxidizers stored in rack storage configurations. The Committee completely revised the document to make it compatible with industry practices and to incorporate enhanced provisions for the safe handling and storage of liquid and solid oxidizers.

Technical Committee on Hazardous Chemicals

William J. Bradford, *Chair*
Brookfield, CT

John A. Davenport, *Vice Chair*
Industrial Risk Insurers, CT
Rep. Industrial Risk Insurers

James E. Benge, Hercules Chemical Specialties Co., DE

James L. Daneker, Los Angeles City Fire Dept., CA

Henry L. Febo, Jr., Factory Mutual Research Corp., MA

Charles L. Gibson, BioLab, Inc., GA

Richard Greenberg, Carteret Fire Dept., NJ

H. Dieter Heinz, Heinz Laboratories Intl., CA

Donald L. Hierman, Rhone-Poulenc, Inc., NJ

John M. Hoffmann, Safety Engr. Labs Inc., MI

Bart Howard, Davenport Fire Dept., IA

Bruce A. Jacobsen, Olin Chemicals Corp., TN

Janice King Jensen, U.S. Environmental Protection Agency, DC

Brad Jones, Jacobson Warehouse Co., Inc., IA

Roland J. Land, Jardine Insurance Brokers, NY

Chester M. McCloskey, The Norac Co. Inc., CA

Robert A. Michaels, RAM TRAC Corp., NY

David P. Nugent, Schirmer Engr. Corp., IL

Anthony M. Ordile, Loss Control Assoc., Inc., PA

Gary A. Page, American Cyanamid Co., NJ

George W. Rambo, GRCS Inc., VA

Gary F. Trojak, Chlorine Inst. Inc., DC
Rep. The Chlorine Inst.

Lynn K. Underwood, Wausau Insurance Cos., WI

Matthew C. Woody, Des Moines Fire Dept., IA

Alternate

Richard D. Gottwald, Society of the Plastics Industry, DC
(Vot. Alt. to SPI Rep.)

Peter F. Langan, Industrial Risk Insurers, CT
(Alt. to J. A. Davenport)

Roger McKim, Wausau Insurance Co., OR
(Alt. to L. K. Underwood)

P. Kirk Mitchell, BioLab, Inc., GA
(Alt. to C. L. Gibson)

Manfred G. Noack, Olin Corp., CT
(Alt. to B. A. Jacobsen)

Nonvoting

Charles H. Ke, U.S. Dept. of Transportation, DC

Samuel J. Porter, Lakeridge, VA
(Member Emeritus)

Robert W. VanDolah, San Diego, CA
(Member Emeritus)

Martha H. Curtis, NFPA Staff Liaison

This list represents the membership at the time the Committee was balloted on the text of this edition. Since that time, changes in the membership may have occurred.

NOTE: Membership on a Committee shall not in and of itself constitute an endorsement of the Association or any document developed by the Committee on which the member serves.

Committee Scope: This Committee shall have primary responsibility for documents on, and maintain current codes for, classes of hazardous chemicals and codes for specific chemicals where these are warranted by virtue of widespread distribution or special hazards.

NFPA 430
Code for the
Storage of Liquid and Solid Oxidizers

1995 Edition

NOTICE: An asterisk (*) following the number or letter designating a paragraph indicates explanatory material on that paragraph in Appendix A.
Information on referenced publications can be found in Chapter 7 and Appendix C.

Chapter 1 General

1-1 Scope.

1-1.1

This code shall apply to the storage of oxidizers that are liquid or solid at ambient conditions.

Exception: This code shall not apply to the storage of solid and liquid oxidizers for normal use on the premises of single-family dwellings.

1-1.1.1 Separate chapters specify requirements for storage of oxidizers by class where the quantities stored are greater than the stated minimums.

1-1.1.2* For quantities of a class of oxidizer that are less than the minimum covered by the separate chapter for that class, those parts of that chapter pertaining to fire prevention and sprinkler protection and compatibility, and all of Chapter 2 of this code shall be used as requirements.

1-1.1.3 Existing buildings storing oxidizers that do not comply with the requirements of this code that pertain to types of construction, separation of buildings, and fixed fire protection shall be used at the discretion of the authority having jurisdiction, provided they do not constitute a distinct hazard to life or adjoining property.

1-1.2

This code shall not apply to explosives or blasting agents, which are covered by NFPA 495, *Explosive Materials Code*; or to ammonium nitrate, which is covered in NFPA 490, *Code for the Storage of Ammonium Nitrate*; or to organic peroxides, which are covered in NFPA 43B, *Code for the Storage of Organic Peroxide Formulations*.

1-1.3

The quantity and arrangement limits in this code shall not apply to the storage of oxidizers at manufacturing plants where oxidizers are manufactured.

1-1.4

The quantity and arrangement limits in this code shall not apply to facilities that use ammonium perchlorate in the commercial manufacture of large-scale rocket motors.

1-2* Purpose.

The purpose of this code shall be to provide reasonable requirements for the safe storage of commercially available strengths of liquid and solid oxidizers. The hazards of stored oxidizers can manifest themselves in one or more of five distinct hazardous situations as follows:

(a) They increase the burning rate of combustible materials.

(b) They can cause spontaneous ignition of combustible materials.

(c) They can decompose rapidly.

(d) They can liberate hazardous gases.

(e) They can undergo self-sustained decomposition, which can result in an explosion.

1-3 Applicability of Other Documents.

The requirements of NFPA 30, *Flammable and Combustible Liquids Code*, and NFPA 231, *Standard for General Storage,* shall apply where applicable and where they are more restrictive than this code.

1-4 Equivalency.

Nothing in this code is intended to prevent the use of systems, methods, or devices equivalent to those prescribed by this code, provided technical documentation is submitted to the authority having jurisdiction that demonstrates equivalency, and the system, method, or device is approved for the intended purpose.

1-5 Definitions.

For the purposes of this code, the following terms are defined below:

Approved.* Acceptable to the authority having jurisdiction.

Authority Having Jurisdiction.* The organization, office, or individual responsible for approving equipment, an installation, or a procedure.

Combustible Containers. Containers that include paper bags, fiber drums, plastic containers, and wooden or fiber boxes or barrels. They also include noncombustible containers having removable combustible liners or packing and include noncombustible containers in combustible overpacks.

Compatible Material. A material that, when in contact with an oxidizer, will not react with the oxidizer or promote or initiate its decomposition.

Explosive Reaction.* A reaction producing a sudden rise in pressure with potentially destructive results. Such a reaction includes both deflagration and detonation.

Incompatible Material. A material that, when in contact with an oxidizer, can cause hazardous reactions or can promote or initiate decomposition of the oxidizer.

Labeled. Equipment or materials to which has been attached a label, symbol, or other identifying mark of an organization that is acceptable to the authority having jurisdiction and concerned with product evaluation that maintains periodic inspection of production of labeled equipment or materials and by whose labeling the manufacturer indicates compliance with appropriate standards or performance in a specified manner.

Listed.* Equipment or materials included in a list published by an organization acceptable to the authority having jurisdiction and concerned with product evaluation that maintains periodic inspection of production of listed equipment or materials and whose listing states either that the equipment or material meets appropriate standards or has been tested and found suitable for use in a specified manner.

Manufacturing Plants. Those facilities where oxidizers are produced by chemical means.

Noncombustible Container. A container constructed of glass or metal. The metal container can be coated with a polymeric material no more than 2 mils in thickness.

Noncombustible Material.* A material that, in the form in which it is used and under the conditions anticipated, will not ignite, supports combustion, burn, or release flammable vapors when subjected to fire or heat. Materials that are reported as having passed ASTM E 136, *Standard Test Method for Behavior of Materials in a Vertical Tube Furnace at 750 Degrees C*, shall be considered noncombustible materials. For the purposes of this code, noncombustible construction and limited-combustible construction are both considered to be noncombustible.

Oxidizer. Any material that readily yields oxygen or other oxidizing gas, or that readily reacts to promote or initiate combustion of combustible materials. Examples of other oxidizing gases include bromine, chlorine, and fluorine.

Pile. Material in a single contiguous storage area. Any material not properly separated by appropriate distance is considered to be part of the same pile.

Processing Plants. Those facilities not located on the premises of manufacturing plants where oxidizers are pelletized, ground, dissolved, packaged, mixed, or blended.

Retail Establishments. Those facilities where oxidizers are sold directly to the general public.

Shall. Indicates a mandatory requirement.

Should. Indicates a recommendation or that which is advised but not required.

Warehouses. Those facilities where oxidizers are received, stored, and subsequently shipped in their original containers.

1-6 Classification of Oxidizers.

For the purpose of this code, oxidizers shall be classified according to the system described in this section. The classification is based on the technical committee’s evaluation of available scientific and technical data, actual experience, and its considered opinion. Classification refers to the pure oxidizer. Gross contamination can cause oxidizers of all classes to undergo exothermic or explosive reaction, particularly if they also are subjected to confinement and heating. (*See definition of oxidizer*.) (*See Sections B-1 through B-4 for oxidizer classifications.*)

1-6.1 Class 1.

An oxidizer whose primary hazard is that it slightly increases the burning rate but does not cause spontaneous ignition when it comes in contact with combustible materials.

1-6.2 Class 2.

An oxidizer that will cause a moderate increase in the burning rate or that causes spontaneous ignition of combustible materials with which it comes in contact.

1-6.3* Class 3.

An oxidizer that will cause a severe increase in the burning rate of combustible materials with which it comes in contact or that will undergo vigorous self-sustained decomposition due to contamination or exposure to heat.

1-6.4* Class 4.

An oxidizer that can undergo an explosive reaction due to contamination or exposure to thermal or physical shock. In addition, the oxidizer will enhance the burning rate and can cause spontaneous ignition of combustibles.

1-7 Classification of Storage Facilities.

1-7.1* Segregated.

Storage in the same room or inside area, but physically separated by distance from incompatible materials.

1-7.2 Cutoff.

Storage in the same building or inside area, but physically separated from incompatible materials by partitions or walls, or storage in a fixed tank.

1-7.3 Detached.

Storage in either an open outside area or a separate building containing no incompatible materials, and located away from all other structures.

Chapter 2 Basic Requirements

2-1 Hazard Management.

2-1.1

The design of a new or enlarged facility for storage of oxidizers shall be reviewed by the authority having jurisdiction. (*For existing structures, see 1-1.1.3.*)

2-1.2

Emergency plans shall be prepared for each facility. These plans shall be reviewed and training exercises shall be conducted at least annually in cooperation with local emergency organizations.

2-2 Identification of Materials in Storage.

2-2.1*

All storage areas containing oxidizers shall be conspicuously identified by the words “Class (appropriate classification number) Oxidizers,” as defined in Section 1-6.

NOTE: The hazard rating classifications for oxidizers do not correlate to the reactivity classification in NFPA 704, *Standard System for the Identification of the Fire Hazards of Materials*.

Exception: Retail display areas.

2-2.2

Where oxidizers having different classifications as defined by Section 1-6 are stored in the same area, the area shall be marked for the most severe hazard class present.

2-2.3

All packages shall be approved and individually marked with the chemical name of the oxidizer.

2-3 Storage Containers, Tanks, and Bins.

2-3.1 Shipping Containers.

Where a storage container for solid and liquid oxidizers also functions as the shipping container, the container shall meet the requirements of the U.S. Department of Transportation or the Canadian Ministry of Transport (Transport Canada).

2-3.2 Tanks and Bins.

Tanks for the storage of bulk liquid oxidizers and bins for the storage of bulk solid oxidizers shall meet the following requirements:

(a) Materials of construction shall be compatible with the oxidizer being stored.

(b) Tanks and bins shall be designed and constructed in accordance with federal, state, and local regulations, or, as a minimum, in accordance with nationally recognized engineering practices (e.g., ASME, API).

(c) Tanks and bins shall be equipped with an adequately sized vent or other relief device to prevent overpressurization due to decomposition or fire exposure.

2-3.3 Bulk Liquid Storage.

Bulk liquid storage is defined as the storage of more than 600 gal (U.S.) (2271 L) in a single container.

2-3.4 Bulk Solid Storage.

Bulk solid storage is defined as the storage of more than 6000 lb (2722 kg) in a single container.

2-3.5 Outside Storage.

Outside storage tank size shall not be limited by this code.

Exception: Class 4 oxidizers.

2-4 Storage Arrangements.

2-4.1

The arrangement and quantity of oxidizers in storage shall depend upon their classification, type of container, type of storage (segregated, cutoff, or detached), and fire protection as specified in succeeding chapters and in the manufacturer's or processor's instructions.

2-4.1.1* The arrangement and quantity of oxidizers in storage shall be permitted to deviate from the requirements of succeeding chapters where specially engineered fire prevention or fire protection systems acceptable to the authority having jurisdiction are provided.

2-4.2*

Oxidizers shall be stored to avoid contact with incompatible materials such as ordinary combustibles, combustible or flammable liquids, greases, and those materials that could react with the oxidizer or promote or initiate its decomposition. These shall not include approved packaging materials, pallets, or other dunnage.

Exception: Hydrogen peroxide (Classes 2 through 4) stored in drums shall not be stored on wooden pallets.

2-4.2.1 Special care shall be taken to prevent any contamination of oxidizers in storage.

2-4.2.2 Where oxidizers are stored in segregated warehouses with flammable liquids, the oxidizer containers and flammable liquid drums shall be separated by at least 25 ft (7.6 m). The separation shall be maintained by dikes, drains, or floor slopes to prevent flammable liquid leakage from encroaching on the separation.

2-4.3

Where Class 2, Class 3, or Class 4 liquid oxidizers are stored, means shall be provided to prevent the liquid oxidizer from flowing out of a cutoff area into an area containing incompatible materials.

2-4.4 Retail Storage of Oxidizers.

2-4.4.1 Oxidizers in retail storage in areas accessible to the public shall be arranged in retail display as described in 2-4.4.2 through 2-4.4.7.

2-4.4.2* Shelves and vertical barriers shall be placed between incompatible materials and shall be solid and of noncombustible construction.

2-4.4.3 Solid oxidizers shall not be stored directly beneath incompatible liquids.

2-4.4.4 Shelves shall be no greater than 24 in. (61 cm) deep.

2-4.4.5 Storage shall be no greater than 6 ft (1.8 m) high.

2-4.4.6 The total amount of all oxidizers in all classes shall be limited to 2 tons (1814 kg) in nonsprinklered areas and 4 tons (3630 kg) in sprinklered areas. Sprinklers shall be designed for the most severe oxidizer class stored.

2-4.4.7 The quantities provided for sprinklered retail sales areas shall be permitted to be applied to a maximum of two sales areas within one retail sales store if the two retail sales areas are separated from each other by a fire partition having at least a 1-hr fire resistance rating.

2-5* Storage Limitations.

Where two or more different classes of oxidizers are stored in the same segregated, cutoff, or detached area, the maximum quantity permitted for each class shall be limited to the sum of the maximum proportion permitted for that class. The total of the proportional amounts shall not exceed 100 percent.

2-6 Other Considerations.

2-6.1

In storage facility design, consideration shall be given to the need to provide for containment. Containment on-site or off-site shall be required where necessary to protect the environment from oxidizers, fire extinguishing agents, and their liquid decomposition products.

2-6.2

Approval of the arrangement of storage shall take into consideration the potential evolution of large quantities of smoke and toxic fumes, especially as storage affects manual fire-fighting operations, building egress, and evacuation of adjacent occupancies or communities.

2-7 Employee Instruction.

2-7.1

Personnel involved in operations where oxidizers are stored shall receive instruction in handling the materials in a safe manner, including the manufacturer's and processor's recommendations.

2-7.2

Particular attention shall be given to proper disposal of spilled material to prevent contamination.

2-8 Heating and Electrical Installations.

2-8.1

Heating shall be arranged so that stored materials cannot be placed in direct contact with heating units, piping, or ducts and oxidizers shall be separated so that they cannot be heated to within 25°F (14°C) of their decomposition temperature or to 120°F (49°C), whichever is lower.

2-8.2

Electrical installations shall be in conformance with NFPA 70, *National Electrical Code®*.

2-9 Smoking.

2-9.1

Smoking shall be prohibited in all storage areas containing oxidizers.

2-9.2

"No Smoking" signs shall be placed conspicuously within and at all entrances to storage areas.

2-10 Maintenance and Repairs.

2-10.1

The performance of maintenance work in an oxidizer storage area shall be subject to prior review and approval by supervisory personnel.

2-10.2

Cutting and welding procedures shall be in conformance with NFPA 51B, *Standard for Fire Prevention in Use of Cutting and Welding Processes*.

2-11 Fire Protection.

2-11.1

Fire hydrants and water supplies shall be provided as required by the authority having jurisdiction. Hydrants shall be installed in accordance with NFPA 24, *Standard for the Installation of Private Fire Service Mains and Their Appurtenances*.

NOTE: Conditions that affect the need for hydrant protection include nearness of the exposures, size and construction of the building, amount and class of the oxidizer stored, and availability of public fire protection.

2-11.2

The need for automatic sprinkler protection shall be determined by the nature of the materials, the manner of storage, and the construction of the buildings under consideration. Where automatic sprinkler systems are required, the systems shall be installed in conformance with NFPA 13, *Standard for the Installation of Sprinkler Systems*.

NOTE: For certain oxidizers in combustible containers, (e.g., calcium hypochlorite in plastic containers) automatic sprinkler protection is effective only for the control of exposure fires.

2-11.3

Only wet-pipe sprinkler systems shall be employed for protection of buildings or areas containing Class 2 or Class 3 oxidizers.

2-11.4 Fire Protection Water Supplies.

2-11.4.1 Water supplies shall be adequate for the protection of the oxidizer storage by hose streams and automatic sprinklers. The water system shall be capable of providing not less than 750 gpm (2840 Lpm) where protection is by means of hose streams, or 500 gpm (1890 Lpm) for hose streams in excess of the automatic sprinkler water demand.

2-11.4.2 Duration of the water supply shall be a minimum of 2 hr.

2-11.5

Water-based fire protection systems shall be inspected, tested, and maintained in accordance with NFPA 25, *Standard for the Inspection, Testing, and Maintenance of Water-Based Fire Protection Systems*.

2-11.6 Manual Fire Fighting.

Manual fire-fighting equipment in the form of portable water extinguishers or water hose reel stations shall be provided in accordance with the requirements of NFPA 10, *Standard for Portable Fire Extinguishers*, and NFPA 14, *Standard for the Installation of Standpipe and Hose Systems*.

2-11.6.1* The placement and use of dry chemical extinguishers containing ammonium compounds (Class A:B:C) shall be prohibited in areas where oxidizers that can release chlorine are stored.

2-11.6.2* Halon extinguishers shall not be used in areas where oxidizers are stored.

2-12 Construction.

Combustible construction materials that could come into contact with oxidizers shall be protected with a compatible coating to prevent impregnation of the combustible materials by the oxidizers.

NOTE: Impregnation of wood for fire retardancy or to prevent decay does not protect the wood from impregnation by the oxidizer.

2-13 Housekeeping and Waste Disposal.

2-13.1

Accumulation of combustible waste in oxidizer storage areas shall be prohibited.

2-13.2

Spilled oxidizers and leaking or broken containers shall be removed immediately to a safe area to await disposal in conformance with applicable regulations and manufacturer’s and processor’s instructions. Spilled materials shall be placed in a clean, separate container and shall not be returned to the original container. The disposal of such materials shall not be combined with that of ordinary trash.

2-13.3

Used, empty, combustible containers shall be stored in a detached or sprinklered area.

2-13.4

Operations shall be arranged to prevent excessive fugitive dust accumulation.

2-13.5

Where absorptive combustible packing materials used to contain water-soluble oxidizers have become wet during either fire or nonfire conditions, the oxidizer can impregnate the packing material. This will create a serious fire hazard when the packing material dries. Wooden pallets that are exposed to water solutions of an oxidizer also can exhibit this behavior. Such material shall be relocated to a safe outside area and shall be disposed of properly.

2-14 Dust Collection Systems.

Dust collection systems shall be provided in accordance with NFPA 91, *Standard for Exhaust Systems for Air Conveying of Materials*. Separate systems shall be provided for incompatible materials.

Chapter 3 Class 1 Oxidizers

3-1 Application.

This chapter shall apply to storage of Class 1 oxidizers where stored in quantities in excess of 4000 lb (1814 kg). Chapter 2 also applies to storage of Class 1 oxidizers.

3-2 Storage Arrangements.

3-2.1

The storage of Class 1 oxidizers shall be segregated, cutoff, or detached.

3-2.2

Storage of Class 1 oxidizers shall be in accordance with Tables 3-2.2(a) and (b).

Table 3-2.2(a) Storage of Class 1 Oxidizers Nonsprinklered Building

	Nonretail Establishment	Retail Establishment*
Building limit (tons)	200 (181 met ton)	15 (13.6 met ton)
Pile limit (tons)	20 (18 met ton)	2 (1.8 met ton)
Pile height (ft)	8 (2.4 m)	6 (1.8 m)
Pile width (ft)	16 (4.9 m)	8 (2.4 m)
Maximum distance from any container to a working aisle (ft)	8 (2.4 m)	4 (1.2 m)
Distance to next pile (ft)	** **	** **
Distance to wall (ft)	4 (1.2 m)	4 (1.2 m)
Distance to incompatible material (ft)	12 (3.7 m)	10 (3 m)

*Totals in this column are for storage in those areas of a retail occupancy not accessible to the public and separated from the sales display area by a minimum of 1-hr fire-resistive construction. For storage in retail sales display areas, see 2-4.4.

**Aisle width equal to pile height.

Table 3-2.2(b) Storage of Class 1 Oxidizers Sprinklered Building*

	Nonretail Establishment	Retail Establishment**
Building limit (tons)	2000 (1814 met ton)	30 (27 met ton)
Pile limit (tons)	200 (181 met ton)	4 (3.6 met ton)
Pile height (ft)	12 (3.7 m)	8 (2.4 m)
Pile width (ft)	24 (7.3 m)	12 (3.7 m)
Maximum distance from any container to a working aisle (ft)	12 (3.7 m)	6 (1.8 m)
Distance to next pile (ft)	*** ***	*** ***
Distance to wall (ft)	2 (0.6 m)	2 (0.6 m)
Distance to incompatible material (ft)	8 (2.4 m)	8 (2.4 m)

*If the storage is to be considered sprinklered, see Section 3-3.

**Totals in this column are for storage in those areas of a retail occupancy not accessible to the public, and separated from the sales display area by a minimum of 1-hr fire-resistive construction. For storage in retail sales display areas, see 2-4.4.

***Aisle width equal to pile height.

3-2.3

The building limit (tons) shall be permitted to be four times the quantities shown in Table 3-2.2(b) if all of the following conditions are met:

(a) Storage is cutoff or detached;

(b) Storage is located in nonretail occupancies; and

(c) Noncombustible containers are used or buildings are noncombustible.

NOTE: Only the building limit, not the pile limit, height, or width, can be increased by this provision.

3-2.4 Bulk Storage.

3-2.4.1 Bulk storage in combustible buildings shall not come in contact with combustible building members unless the members are protected by a compatible coating to prevent their impregnation by the oxidizer. (*See Section 2-12.*)

3-2.4.2 Bulk storage, either in permanent bins or in piles, shall be separated from all other materials.

3-2.4.3 Bins shall be of noncombustible construction.

Exception: Wooden bins shall be permitted to be protected with a compatible coating to prevent impregnation of the combustible material by the oxidizer.

3-2.4.4 Storage shall be managed to prevent excessive dust accumulation.

3-3 Sprinkler Protection.

3-3.1

Sprinkler protection for Class 1 oxidizers shall be in accordance with NFPA 231, *Standard for General Storage*, or NFPA 231C, *Standard for Rack Storage of Materials*, whichever is applicable.

3-3.2*

For the purpose of applying the requirements of NFPA 231, *Standard for General Storage*, or NFPA 231C, *Standard for Rack Storage of Materials*, Class 1 oxidizers in noncombustible or combustible containers (paper bags or noncombustible containers with removable combustible liners) shall be designated as a Class 1 commodity; as a Class 2 commodity where contained in fiber packs or noncombustible containers in combustible packaging; and as a Class 3 commodity where contained in plastic containers.

3-3.3

Sprinkler protection shall be installed in accordance with NFPA 13, *Standard for Installation of Sprinkler Systems*.

Chapter 4 Class 2 Oxidizers

4-1 Application.

This chapter shall apply to Class 2 oxidizers where stored in quantities in excess of 1000 lb (454 kg). Chapter 2 also applies to storage of Class 2 oxidizers.

4-2 Storage Arrangements.

4-2.1

The storage of Class 2 oxidizers shall be segregated, cutoff, or detached.

Table 4-2.3(a) Storage of Class 2 Oxidizers Nonsprinklered Building

	Segregated Storage		Cutoff Storage		Detached St
	Process Plant General Warehouse	Retail* Establishment	Process Plant General Warehouse	Retail* Establishment	
Building limit (tons)	50 (45 met ton)	10 (8.8 met ton)	200 (181 met ton)	15 (13.6 met ton)	300 (272 met tor
Pile limit (tons)	10 (8.8 met ton)	1 (0.91 met ton)	20 (18.1 met ton)	2 (1.8 met ton)	30 (27.2 met tor
Pile height (ft)	6 (1.8 m)	4 (1.2 m)	8 (2.4 m)	8 (2.4 m)	8 (2.4 m)
Pile width (ft)	8 (2.4 m)	8 (2.4 m)	12 (3.7 m)	8 (2.4 m)	16 (4.9 m)
Maximum distance from any container to a working aisle (ft)	4 (1.2 m)	4 (1.2 m)	6 (1.8 m)	4 (1.2 m)	8 (2.4 m)
Distance to next pile (ft)	** **	** **	** **	** **	** **
Distance to wall (ft)	4 (1.2 m)	4 (1.2 m)	4 (1.2 m)	4 (1.2 m)	4 (1.2 m)
Distance to incompatible material (ft)	12 (3.7 m)	12 (3.7 m)	*** ***	*** ***	*** ***

*Totals in this column are for storage in those areas of a retail occupancy not accessible to the public and separated from the sales display area by a cutoff wall in accordance with 4-2.2. For storage in retail sales display areas, see 2-4.4.

**Aisle width equal to pile height.

***Not permitted by definition.

Table 4-2.3(b) Storage of Class 2 Oxidizers Sprinklered Building*

	Segregated Storage		Cutoff Storage		Detached Stora
	Process Plant General Warehouse	Retail** Establishment	Process Plant General Warehouse	Retail** Establishment	
Building limit (tons)	100 (91 met ton)	20 (18.1 met ton)	1000 (907 met ton)	30 (27.2 met ton)	2000 (1814 met to
Pile limit (tons)	20 (18.1 met ton)	2 (1.8 met ton)	100 (91 met ton)	5 (4.5 met ton)	200 (181 met ton)
Pile height*** (ft)	*** ***	*** ***	*** ***	*** ***	*** ***

Pile width (ft)	16 (4.9 m)	8 (2.4 m)	25 (7.6 m)	8 (2.4 m)	25 (7.6 m)
Maximum distance from any container to a working aisle (ft)	8 (2.4 m)	4 (1.2 m)	12 (3.7 m)	6 (1.8 m)	12 (3.7 m)
Distance to next pile (ft)	**** ****	**** ****	**** ****	**** ****	**** ****
Distance to wall (ft)	2 (0.6 m)	2 (0.6 m)	2 (0.6 m)	2 (0.6 m)	2 (0.6 m)
Distance to incompatible material (ft)	12 (3.7 m)	12 (3.7 m)	***** *****	***** *****	***** *****

*If the storage is considered to be sprinklered, see Section 4-4.

**Totals in this column are for storage in those areas of a retail occupancy not accessible to the public and separated from the sales display area by a cutoff wall in accordance with 4-2.2. For storage in retail sales display areas see 2-4.4.

***See 4-2.7 and Table 4-4.1.

****Aisle width equal to pile height.

*****Not permitted by definition.

4-2.2

Cutoff walls shall have a fire resistance rating of at least 1 hr.

4-2.3

Storage of Class 2 oxidizers shall be in accordance with Tables 4-2.3(a) and (b).

4-2.4

The building limit (tons) shall be permitted to be four times the quantities shown in Table 4-2.3(b) if all of the following conditions are met:

(a) Storage is cutoff or detached;

(b) Storage is located in nonretail occupancies; and

(c) Noncombustible containers are used or buildings are noncombustible.

NOTE: Only the building limit, not the pile limit, height, or width, can be increased by this provision.

4-2.5

Storage in glass carboys shall not be more than two carboys high.

4-2.6

Storage in basements shall be prohibited.

Exception: Where the oxidizer is stored in fixed tanks.

4-2.7 Maximum Height of Storage.

4-2.7.1 Maximum storage height for nonsprinklered buildings shall be in accordance with Table 4-2.3(a).

4-2.7.2 Maximum storage height for sprinklered buildings shall be in accordance with Table 4-4.1.

4-3 Building Construction.

4-3.1

Construction materials that are permitted to be in contact with oxidizers, all cutoff partitions, and all construction in stories or basements below storage of liquid oxidizers shall be noncombustible.

4-3.2

Storage areas for oxidizing materials in combustible containers shall be provided with means to vent fumes in a fire emergency.

4-4 Sprinkler Protection.

4-4.1*

Sprinkler protection for Class 2 oxidizers shall be designed in accordance with Table 4-4.1.

Table 4-4.1 Sprinkler Protection for Class 2 Oxidizers

		Ceiling Sprinklers		
Type of Storage	**Storage Height ft (m)**	**Density gpm/ft² (L/min/m²)**	**Area of Application ft² (m²)**	**In-Rack Sprinklers**
Palletized or	8 (2.4)	0.20 (8)	3750 (348)	
Bulk	12 (3.7)	0.35 (14)	3750 (348)	
Rack	12 (3.7)	0.20 (8)	3750 (348)	One line above each level of storage except the top level
	16 (4.9)	0.30 (12)	2000 (186)	

4-4.2

Sprinkler protection shall be installed in accordance with NFPA 13, *Standard for the Installation of Sprinkler Systems.*

4-4.3

Ceiling sprinklers shall have heads rated at 286°F (141°C).

4-4.4 Storage Protection with In-Rack Sprinklers.

4-4.4.1 In-rack sprinklers shall be heads rated at 165°F (74°C) and shall be designed to provide 30 psi (207 kPa) on the hydraulically most remote six heads on each level.

4-4.4.2 The in-rack sprinklers shall be spaced on 8-ft to 10-ft (2.4-m to 3.0-m) centers at rack uprights.

4-4.4.3 Where multiple levels are provided, the in-rack sprinklers shall be staggered and shall be provided with water shields.

4-5 Detached Storage.

4-5.1

To be considered detached, a sprinklered building for storage of Class 2 oxidizers shall be a minimum of 35 ft (10.7 m) from other buildings and from a line of property that can be built upon.

4-5.2

To be considered detached, a nonsprinklered building for storage of Class 2 oxidizers shall be located no less than 50 ft (15.2 m) from other buildings or a line of property that can be built upon.

Chapter 5 Class 3 Oxidizers

5-1 Application.

This chapter shall apply to Class 3 oxidizers where stored in quantities in excess of 200 lb (91 kg). Chapter 2 also applies to storage of Class 3 oxidizers.

5-2 Storage Arrangements.

5-2.1

The storage of Class 3 oxidizers shall be segregated, cutoff, or detached.

Exception: Storage for sodium chlorate, potassium chlorate, sodium bromate, potassium bromate, and ammonium dichromate shall only be cutoff or detached, not segregated.

Table 5-2.4(a) Storage of Class 3 Oxidizers Nonsprinklered Building

	Segregated Storage		**Cutoff Storage**		**Detached Storag**
	Process Plant General Warehouse	**Retail* Establishment**	**Process Plant General Warehouse**	**Retail* Establishment**	
Building limit (tons)	20 (18.1 met ton)	10 (8.8 met ton)	100 (91 met ton)	15 (13.6 met ton)	200 (181 met ton)
Pile limit (tons)	5 (4.5 met ton)	1.0 (0.91 met ton)	10 (9.1 met ton)	2 (1.8 met ton)	30 (27.2 met ton)
Pile height (ft)	6 (1.8 m)	4 (1.2 m)	6 (1.8 m)	6 (1.8 m)	6 (1.8 m)
Pile width (ft)	8 (2.4 m)	4 (1.2 m)	12 (3.7 m)	8 (2.4 m)	12 (3.7 m)
Maximum distance from any container to a working aisle (ft)	4 (1.2 m)	4 (1.2 m)	8 (2.4 m)	4 (1.2 m)	8 (2.4 m)
Distance to next pile (ft)	** **	** **	** **	** **	** **
Distance to wall (ft)	4 (1.2 m)	4 (1.2 m)	4 (1.2 m)	4 (1.2 m)	4 (1.2 m)
Distance to incompatible material (ft)	12 (3.7 m)	12 (3.7 m)	*** ***	*** ***	*** ***

*Totals in this column are for storage in those areas of a retail occupancy not accessible to the public and separated from the sales display area by a cutoff wall in accordance with 5-2.3. For storage in retail sales display areas see 2-4.4.
**Aisle width equal to pile height.
***Not permitted by definition.

Table 5-2.4(b) Storage of Class 3 Oxidizers Sprinklered Building*

	Segregated Storage		Cutoff Storage		Detached Storag
	Process Plant General Warehouse	Retail** Establishment	Process Plant General Warehouse	Retail** Establishment	
Building limit (tons)	50 (45 met ton)	20 (18.1 met ton)	500 (454 met ton)	30 (27.2 met ton)	1500 (1360 met to
Pile limit (tons)	10 (8.8 met ton)	2 (1.8 met ton)	30 (27.2 met ton)	4 (3.6 met ton)	100 (91 met ton)
Pile height*** (ft)	*** ***	*** ***	*** ***	*** ***	*** ***
Pile width (ft)	12 (3.7 m)	8 (2.4 m)	16 (4.9 m)	8 (2.4 m)	20 (6.1 m)
Maximum distance from any container to a working aisle (ft)	8 (2.4 m)	4 (1.2 m)	10 (3 m)	6 (1.8 m)	10 (3 m)
Distance to next pile (ft)	**** ****	**** ****	**** ****	**** ****	**** ****
Distance to wall (ft)	2 (0.6 m)	2 (0.6 m)	2 (0.6 m)	2 (0.6 m)	2 (0.6 m)
Distance to incompatible material (ft)	12 (3.7 m)	12 (3.7 m)	***** *****	***** *****	***** *****

*If the storage is considered to be sprinklered, the sprinkler system shall be designed in accordance with the requirements of Section 5-4.
**Totals in this column are for storage in those areas of a retail occupancy not accessible to the public and separated from the sales display area by a cutoff wall in accordance with 5-2.3. For storage in retail sales display areas see 2-4.4.
***See 5-2.8 and Table 5-4.1.
****Aisle width equal to pile height.
*****Not permitted by definition.

5-2.2

Class 3 oxidizer storage shall be located on the ground floor only.

5-2.3

Cutoff walls shall have a fire resistance rating of at least 2 hr.

5-2.4

Storage of Class 3 oxidizers shall be in accordance with Tables 5-2.4(a) and (b).

5-2.5

The building limit (tons) shall be permitted to be twice the quantities shown in Table 5-2.4(b) if all of the following conditions are met:

(a) Storage is cutoff or detached;

(b) Noncombustible containers are used or buildings are noncombustible; and

(c) Storage is located in nonretail occupancies.

NOTE: Only the building limit, not the pile limit, height, or width, can be increased by this provision.

5-2.6

Storage in glass carboys shall be one carboy high.

5-2.7

Bulk storage in open bins or piles shall not be permitted.

5-2.8 Maximum Height of Storage.

5-2.8.1 Maximum storage height for nonsprinklered buildings shall be in accordance with Table 5-2.4(a).

5-2.8.2 Maximum storage height for sprinklered buildings shall be in accordance with Table 5-4.1.

5-3 Building Construction.

5-3.1

Buildings used for the storage of liquid Class 3 oxidizers shall not have basements.

5-3.2

Construction materials that can come in contact with oxidizers shall be noncombustible.

5-3.3

Storage areas for oxidizing materials in combustible containers shall be provided with means to vent fumes in a fire emergency.

5-4 Sprinkler Protection.

5-4.1*

Sprinkler protection for Class 3 oxidizers shall be designed in accordance with Table 5-4.1.

Table 5-4.1 Sprinkler Protection for Class 3 Oxidizers

Type of Storage	Storage Height ft (m)	Density gpm/ft^2 (L/min/m^2)	Area of Application ft^2 (m^2)	In-Rack Sprinklers
Palletized or	5 (1.5)	0.35 (14)	5000 (465)	
Bulk	10 (3)	0.65 (26)	5000 (465)	
Rack	10 (3)	0.35 (14)	5000 (465)	1 level at midpoint of rack.

5-4.2

Sprinkler protection shall be installed in accordance with NFPA 13, *Standard for Installation of Sprinkler Systems*.

5-4.3

Ceiling sprinklers shall be heads rated at 286°F (141°C).

5-4.4 Storage Protection with In-Rack Sprinklers.

5-4.4.1 In-rack sprinklers shall be heads rated at 165°F (74°C) and shall be designed to provide 30 psi (207 kPa) on the hydraulically most remote six heads on each level.

5-4.4.2 The in-rack sprinklers shall be spaced on 8-ft to 10-ft (2.4-m to 3.0-m) centers at rack uprights.

5-4.4.3 Where multiple levels are provided, the in-rack sprinklers shall be staggered and shall be provided with water shields.

5-5 Detached Storage.

To be considered detached, a building for storage of Class 3 oxidizers shall be separated from flammable or combustible liquid storage, flammable gas storage, combustible material in the open, and from any inhabited building, passenger railroad, public highway, or other tanks. The minimum separation distance shall be:

(a) 50 ft (15 m) for a sprinklered building, or

(b) 75 ft (23 m) for an unsprinklered building.

Chapter 6 Class 4 Oxidizers

6-1 Application.

This chapter shall apply to Class 4 oxidizers where stored in quantities in excess of 10 lb (4.5 kg). Chapter 2 also applies to storage of Class 4 oxidizers.

6-2 Storage Arrangements.

6-2.1

The storage of Class 4 oxidizers shall be detached.

6-2.2

Storage in glass carboys shall be one carboy high. Storage in drums or in containers or in cases shall not exceed the limits outlined in Table 6-2.2.

Table 6-2.2 Storage of Class 4 Oxidizers in Drums, Containers, Cases

	Nonsprinklered Building	Sprinklered Building

Piles		
Length (ft)	10 (3.0 m)	10 (3.0 m)
Width (ft)	4 (1.2 m)	4 (1.2 m)
Height (ft)	4 (1.2 m)	8 (2.4 m)
Distance to next pile (ft)	6 (1.8 m)	8 (2.4 m)
Quantity Limit per building (tons)	1 (0.9 met tons)	No Limit

6-2.3

Bulk storage in piles or fixed bins shall not be permitted.

6-3 Building Construction and Location.

6-3.1

Buildings shall be constructed as one story without basement. Construction materials that could come in contact with oxidizers shall be noncombustible.

6-3.2

Storage areas shall be provided with means to vent fumes in an emergency.

6-3.3

A storage building or storage tank shall be located not less than the minimum distance provided in Table 6-3.4 from flammable liquid storage, combustible material in the open, and from any inhabited building, passenger railroad, public highway, property line, or tank (other than oxidizer storage).

6-3.4*

Where tanks are not separated from each other by 10 percent of the distance specified in Table 6-3.4 for the largest tank, the total contents of all tanks shall be used when using Table 6-3.4.

Table 6-3.4 Separation of Buildings, Tanks Containing Class 4 Oxidizers

Weight of Class 4 Oxidizer		**Distance**	
(lb)	**(kg)**	**(ft)**	**(m)**
over 10 to 100	(4.5 to 45.4)	75	(23)
101 to 500	(45.8 to 227)	100	(30)
501 to 1,000	(227 to 454)	125	(38)
1,001 to 3,000	(454 to 1361)	200	(61)
3,001 to 5,000	(1361 to 2268)	300	(91)
5,001 to 10,000	(2268 to 4536)	400	(122)

over 10,000	(over 4536)	Subject to approval by the authority having jurisdiction.

6-4 Sprinkler Protection.

6-4.1

Sprinkler protection for Class 4 oxidizers shall be installed on a deluge sprinkler system to provide water density of 0.35 gal/min/ft^2 (14.4 L/min/m^2) over the entire storage area.

6-4.2

Sprinkler protection shall be installed in accordance with NFPA 13, *Standard for the Installation of Sprinkler Systems*.

Chapter 7 Referenced Publications

7-1

The following documents or portions thereof are referenced within this code and shall be considered part of the requirements of this document. The edition indicated for each reference is the current edition as of the date of the NFPA issuance of this document.

7-1.1 NFPA Publications.

National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.

NFPA 10, *Standard for Portable Fire Extinguishers*, 1994 edition.

NFPA 13, *Standard for the Installation of Sprinkler Systems*, 1994 edition.

NFPA 14, *Standard for the Installation of Standpipe and Hose Systems*, 1993 edition.

NFPA 24, *Standard for the Installation of Private Fire Service Mains and Their Appurtenances*, 1995 edition.

NFPA 25, *Standard for the Inspection, Testing, and Maintenance of Water-Based Fire Protection Systems*, 1995 edition.

NFPA 30, *Flammable and Combustible Liquids Code*, 1993 edition.

NFPA 43B, *Code for the Storage of Organic Peroxide Formulations*, 1993 edition.

NFPA 51B, *Standard for Fire Prevention in Use of Cutting and Welding Processes*, 1994 edition.

NFPA 70, *National Electrical Code*, 1996 edition.

NFPA 91, *Standard for the Installation of Systems for Air Conveying of Materials*, 1995 edition.

NFPA 231, *Standard for General Storage*, 1995 edition.

NFPA 231C, *Standard for Rack Storage of Materials*, 1995 edition.

NFPA 490, *Code for the Storage of Ammonium Nitrate*, 1993 edition.

NFPA 495, *Explosive Materials Code*, 1992 edition.

7-1.2 Other Publications.

7-1.2.1 ASTM Publication. American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103.

ASTM E 136, *Standard Test Method for Behavior of Materials in a Vertical Tube Furnace at 750 Degrees C*, 1994.

7-1.2.2 Canadian Government Publication.

Canadian Ministry of Transport Regulations.

7-1.2.3 U.S. Government Publication. U.S. Government Printing Office, Superintendent of Documents, Washington, DC 20402.

Title 49, *Code of Federal Regulations*, Parts 100 to end.

Appendix A Explanatory Material

This Appendix is not a part of the requirements of this NFPA document but is included for informational purposes only.

A-1-1.1.2 NFPA 49, *Hazardous Chemicals Data*, and NFPA 491M, *Manual of Hazardous Chemical Reactions*, should be used for guidance.

A-1-2

The decomposition of stored commercially available strengths of liquid and solid oxidizers can emit toxic gases. Additionally, the runoff from spills of stored oxidizers or from oxidizers mixed with fire extinguishing agents can contain materials hazardous to the environment.

A-1-5 Approved. The National Fire Protection Association does not approve, inspect, or certify any installations, procedures, equipment, or materials; nor does it approve or evaluate testing laboratories. In determining the acceptability of installations, procedures, equipment, or materials, the authority having jurisdiction may base acceptance on compliance with NFPA or other appropriate standards. In the absence of such standards, said authority may require evidence of proper installation, procedure, or use. The authority having jurisdiction may also refer to the listings or labeling practices of an organization concerned with product evaluations that is in a position to determine compliance with appropriate standards for the current production of listed items.

A-1-5 Authority Having Jurisdiction.

The phrase "authority having jurisdiction" is used in NFPA documents in a broad manner, since jurisdictions and approval agencies vary, as do their responsibilities. Where public safety is primary, the authority having jurisdiction may be a federal, state, local, or other regional department or individual such as a fire chief; fire marshal; chief of a fire prevention bureau, labor department, or health department; building official; electrical inspector; or others having statutory authority. For insurance purposes, an insurance inspection department, rating bureau, or other insurance company representative may be the authority having jurisdiction. In many circumstances, the property owner or his or her designated agent assumes the role of the authority having jurisdiction; at government installations, the commanding officer or departmental official may be the authority having jurisdiction.

A-1-5 Explosive Reaction.

For further information on venting explosive reactions, see NFPA 68, *Guide for Venting of Deflagrations*.

A-1-5 Listed.

The means for identifying listed equipment may vary for each organization concerned with product evaluation, some of which do not recognize equipment as listed unless it is also labeled. The authority having jurisdiction should utilize the system employed by the listing organization to identify a listed product.

A-1-5 Noncombustible Material.

See NFPA 220, *Standard on Types of Building Construction*.

A-1-6.3

The term contamination in this definition means minor contamination that can occur if the material is spilled or placed into improperly cleaned equipment. It does not mean gross contamination with large quantities of combustibles or incompatible materials.

A-1-6.4

The term contamination in this definition means minor contamination that can occur if the material is spilled or placed into improperly cleaned equipment. It does not mean gross contamination with large quantities of combustibles or incompatible materials.

A-1-7.1

Sills, curbs, or intervening storage of nonhazardous compatible materials and aisles should be used as aids in maintaining separation.

A-2-2.1

The classification system described in Section 1-7 should be used only to determine the storage requirements established by this code. It is not meant to be a substitute for the hazard identification system established by NFPA 704, *Standard System for the Identification of the Fire Hazards of Materials*. Since the hazard characteristics of oxidizers vary widely depending on the type of oxidizer and its relative concentration, each oxidizer should be rated individually according to the criteria established in NFPA 704.

NFPA 704 is designed to apprise fire fighters or emergency personnel of the inherent hazards related to the manufacture, storage, or use of hazardous materials. It is concerned with the health, fire, reactivity, and other related hazards created by short-term exposure that might be encountered under fire or related emergency conditions.

A-2-4.1.1 Automatic sprinklers should not be relied upon to control all fires involving oxidizers packed in plastic containers.

A-2-4.2

Care should be exercised, since some oxidizers are mutually incompatible. Triazinetriones (chlorinated isocyanurates) and hypochlorites are examples of oxidizers that are incompatible. NFPA 491M, *Manual of Hazardous Chemical Reactions*, lists many oxidizers and other materials that result in hazardous interactions.

A-2-4.4.2 Recommended retail store arrangements for mutually incompatible oxidizers are shown in Figures A-2-4.4.2(a) and (b). These two diagrams illustrate arrangements that minimize the chance of contamination between incompatible materials. Wherever possible, vertical separation should be maintained between incompatible materials.

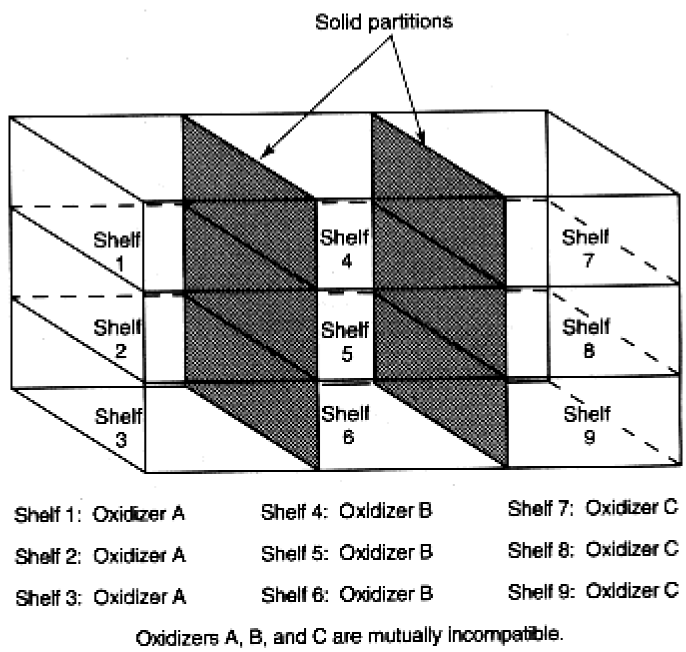


Figure A-2-4.4.2(a) Recommended retail store arrangement for mutually incompatible oxidizers.

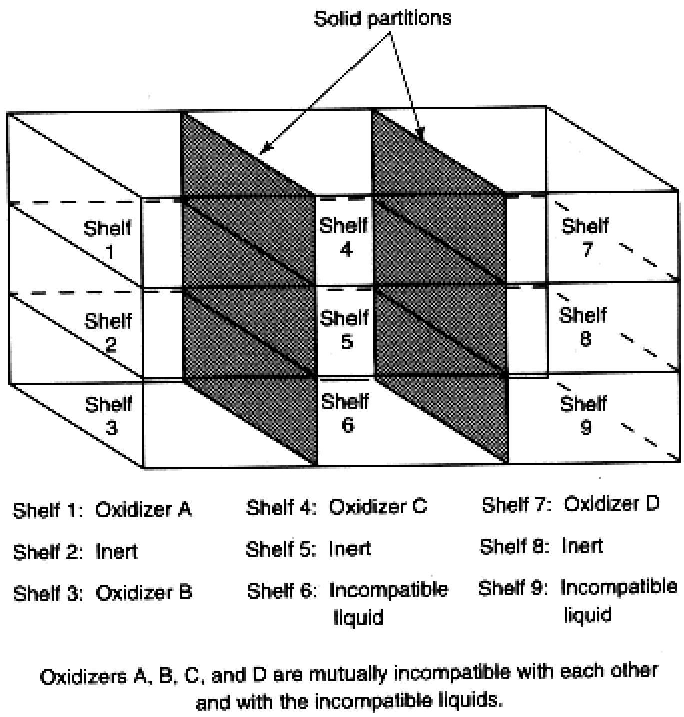


Figure A-2-4.4.2(b) Recommended retail store arrangement for mutually incompatible oxidizers and other incompatible materials.

A-2-5

Example: A sprinklered warehouse containing both Class 2 and Class 3 oxidizers in combustible containers that are cut off from other storage by a 2-hr fire separation is permitted to contain 500 tons (454,000 kg) of Class 2 oxidizers and 250 tons (227,000 kg) of Class 3 oxidizers in accordance with the following ratios:

$$\frac{500 \text{ tons}}{1000 \text{ tons (max)}} \times 100 = 50\% \text{ Class 2}$$

$$\frac{250 \text{ tons}}{500 \text{ tons (max)}} \times 100 = 50\% \text{ Class 3}$$

SI units: 1 lb = 0.454 kg

In no case should a quantity in storage exceed the maximum for its class, nor should the sum of the percentages exceed 100 percent.

A-2-11.6.1 A dry chemical fire extinguishing agent containing ammonium compounds (such as some A:B:C agents) should not be used on oxidizers that contain chlorine. The reaction between the oxidizer and the ammonium salts in the fire extinguishing agent can produce an explosive compound (NCl_3). Carbon dioxide or other extinguishing agents that function by a smothering action for effective use are of no value in extinguishing fires involving oxidizers.

A-2-11.6.2 Halon extinguishers should not be used on fires involving oxidizers, since they can react with the oxidizer.

A-3-3.2

Commodity refers to the definition in NFPA 231, *Standard for General Storage*, or NFPA 231C, *Standard for Rack Storage of Materials*, as appropriate.

A-4-4.1

For the purposes of Table 4-4.1, the fire hazard potential of Class 2 oxidizers has been considered as approximately equal to Group A plastic (non-expanded), stable cartoned, in accordance with NFPA 231, *Standard for General Storage*, and comparable sections of NFPA 231C, *Standard for Rack Storage of Materials.*

A-5-4.1

For the purposes of Table 5-4.1, the sprinkler density has been derived from fire loss history.

A-6-3.4

For example, two tanks contain 4000 lb (1814 kg) and 3000 lb (1360 kg) of Class 4 oxidizer and they are separated by 25 ft (7.6 m). Since they are separated by less than 10 percent of 300 ft (92 m), the total quantity of 7000 lb (3175 kg) requires a minimum separation of 400 ft (122 m) to the nearest important structure in accordance with 6-3.3.

Appendix B Typical Oxidizers
(Unless concentration is specified, undiluted material is referenced.)

This Appendix is not a part of the requirements of this NFPA document but is included for informational purposes only.

B-1 Typical Class 1 Oxidizers.

All inorganic nitrates (unless otherwise classified)

All inorganic nitrites (unless otherwise classified)

Ammonium persulfate

Barium peroxide

Calcium peroxide

Hydrogen peroxide solutions (greater than 8 percent up to 27.5 percent)

Lead dioxide

Lithium hypochlorite (39 percent or less available chlorine)

Lithium peroxide

Magnesium peroxide

Manganese dioxide

Nitric acid (40 percent concentration or less)

Perchloric acid solutions (less than 50 percent by weight)
Potassium dichromate
Potassium percarbonate
Potassium persulfate
Sodium carbonate peroxide
Sodium dichloro-s-triazinetrione dihydrate
Sodium dichromate
Sodium perborate (anhydrous)
Sodium perborate monohydrate
Sodium perborate tetrahydrate
Sodium percarbonate
Sodium persulfate
Strontium peroxide
Trichloro-s-triazinetrione (trichloroisocyanuric acid) (all forms)
Zinc peroxide

B-2 Typical Class 2 Oxidizers.

Barium bromate
Barium chlorate
Barium hypochlorite
Barium perchlorate
Barium permanganate
1-Bromo-3-chloro-5,5-dimethylhydantoin (BCDMH)
Calcium chlorate
Calcium chlorite
Calcium hypochlorite (50 percent or less by weight)
Calcium perchlorate
Calcium permanganate
Chromium trioxide (chromic acid)
Copper chlorate
Halane (1,3-dichloro-5,5-dimethylhydantoin)
Hydrogen peroxide (greater than 27.5 percent up to 52 percent)
Lead perchlorate
Lithium chlorate
Lithium hypochlorite (more than 39 percent available chlorine)
Lithium perchlorate
Magnesium bromate

Magnesium chlorate
Magnesium perchlorate
Mercurous chlorate
Nitric acid (more than 40 percent but less than 86 percent)
Nitrogen tetroxide
Perchloric acid solutions (more than 50 percent but less than 60 percent)
Potassium perchlorate
Potassium permanganate
Potassium peroxide
Potassium superoxide
Silver peroxide
Sodium chlorite (40 percent or less by weight)
Sodium perchlorate
Sodium perchlorate monohydrate
Sodium permanganate
Sodium peroxide
Strontium chlorate
Strontium perchlorate
Thallium chlorate
Urea hydrogen peroxide
Zinc bromate
Zinc chlorate
Zinc permanganate

B-3 Typical Class 3 Oxidizers.

Ammonium dichromate
Calcium hypochlorite (over 50 percent by weight)
Chloric acid (10 percent maximum concentration)
Hydrogen peroxide solutions (greater than 52 percent up to 91 percent)
Mono-(trichloro)-tetra-(monopotassium dichloro)-penta-s-triazinetrione
Nitric acid, fuming (more than 86 percent concentration)
Perchloric acid solutions (60 percent to 72 percent by weight)
Potassium bromate
Potassium chlorate
Potassium dichloro-s-triazinetrione (potassium dichloroisocyanurate)
Sodium bromate
Sodium chlorate

Sodium chlorite (over 40 percent by weight)

Sodium dichloro-s-triazinetrione (sodium dichloroisocyanurate)

B-4 Typical Class 4 Oxidizers.

Ammonium perchlorate (particle size greater than 15 microns)

Ammonium permanganate

Guanidine nitrate

Hydrogen peroxide solutions (greater than 91 percent)

Tetranitromethane

NOTE: Ammonium perchlorate less than 15 microns is classified as an explosive and, as such, is not covered by this code. (*See NFPA 495, Explosive Materials Code.*)

Appendix C Referenced Publications

C-1

The following documents or portions thereof are referenced within this code for informational purposes only and thus are not considered part of the requirements of this document. The edition indicated for each reference is the current edition as of the date of the NFPA issuance of this document.

C-1.1 NFPA Publications.

National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.

NFPA 49, *Hazardous Chemicals Data*, 1994 edition.

NFPA 68, *Guide for Venting of Deflagrations,* 1994 edition.

NFPA 220, *Standard on Types of Building Construction,* 1995 edition.

NFPA 231, *Standard for General Storage*, 1995 edition.

NFPA 231C, *Standard for Rack Storage of Materials*, 1995 edition.

NFPA 491M, *Manual of Hazardous Chemical Reactions*, 1991 edition.

NFPA 495, *Explosive Materials Code*, 1992 edition.

NFPA 704, *Standard System for the Identification of the Fire Hazards of Materials*, 1990 edition.

Recommended Practice for Responding to Hazardous Materials Incidents

1997 Edition

This edition of NFPA 471, *Recommended Practice for Responding to Hazardous Materials Incidents*, was prepared by the Technical Committee on Hazardous Materials Response Personnel and acted on by the National Fire Protection Association, Inc., at its Fall Meeting held November 18-20, 1996, in Nashville, TN. It was issued by the Standards Council on January 17, 1997, with an effective date of February 7, 1997, and supersedes all previous editions.

Changes other than editorial are indicated by a vertical rule in the margin of the pages on which they appear. These lines are included as an aid to the user in identifying changes from the previous edition.

This edition of NFPA 471 was approved as an American National Standard on February 7, 1997.

Origin and Development of NFPA 471

At the July 1985 NFPA Standards Council meeting, approval was given to the concept of a new project on Hazardous Materials Response Personnel. The Council directed that a proposed scope and start-up roster for the new Committee be prepared, taking into account the need to expand the Committee membership beyond the fire service and the application beyond “professional qualifications.”

When establishment of the Committee was formally announced, many requests for membership were received, and similar requests continued to arrive during the first year of its existence. The first meeting of the Committee took place in October 1986. Since that opening session, five additional meetings were held to complete work on this document.

Interest in the subject of hazardous materials, especially as it relates to the emergency responder, continues at a high level. Some of this interest is due to an increased awareness of the magnitude of the problem; much of it can be credited to federal regulations that will have an impact on all responders.

In 1993 the Committee began reviewing this document for the purpose of revising it. The Committee has made several changes to this 1997 edition in order to ensure that the document remains consistent with NFPA 472, *Standard for Professional Competence of Responders to Hazardous Materials Incidents*.

The gratitude of the Committee is extended to all who participated in the development process, and especially to the non-Committee members who helped so much.

Technical Committee on Hazardous Materials Response Personnel

Peter A. McMahon, *Chair*
Principal Financial Group, NY [U]
Rep. Grand Island Fire Dept.

Gerald L. Grey, *Vice Chair*
San Francisco Fire Dept., CA [U]
Rep. The Alliance for Fire & Emergency Mgmt.

Charles J. Wright, *Secretary*
Union Pacific Railroad Co., NE [SE]

Donald Beckering, Hennepin Technical College, MN [U]

Glenn P. Benarick, Fairfax County Fire & Rescue, VA [E]

Bud Berry, 3M, MN [M]
Rep. American Society of Safety Engr

Gene P. Carlson, Oklahoma State University, OK [U]
Rep. Int'l Fire Service Training Assn.

Don L. Crowson, Arlington Fire Dept., TX [U]

Thomas F. Dalton, Consulting Services Inc., NJ [U]
Rep. Spill Control Assn. of America

James L. Daneker, Los Angeles City Fire Dept., CA [C]

Jeffery C. Davis, Assn. of American Railroads, CO [RT]

Manuel A. Ehrlich, Jr., BASF Corp., NJ [M]
Rep. Chemical Mfrs. Assn.

James A. Engman, Ansul Inc., WI [M]

John M. Eversole, Chicago Fire Dept., IL [E]
Rep. Int'l Assn. of Fire Chiefs

Remmit P. R. Gaade, Toronto Fire Dept., Ontario, Canada [E]

Thomas J. Haring, New York City Fire Dept., NY [E]

Gerald L. Grey, San Francisco Fire Dept., CA [U]
Rep. The Alliance for Fire and Emergency Mgmt.

H. Dieter Heinz, Heinz Laboratories Int'l, CA [E]

Rep. California State Firefighters' Assn.

John T. Higgins, Dow Corning Corp., MI [U]
Rep. NFPA Industrial Fire Protection Section

Charles L. Keller, Assn. of American Railroads, DC [E]

Louis J. Klein, Volunteer Firemens Insurance Services, PA [I]

Jan D. Kuczma, U.S. Fire Administration, MD [SE]

M. Jo McMullen, Summit County Hazardous Materials Response Team, OH [SE]

Mary Beth Michos, Prince William County Dept. of Fire/Rescue, VA [E]

Gregory G. Noll, Hildebrand & Noll Assoc., Inc., PA [SE]

Irving Owens, Rhode Island State Fire Marshal, RI [E]
Rep. Fire Marshals Assn. of North America

Daniel Gary Snell, Houston Fire Dept., TX [U]

William H. Stringfield, William H. Stringfield & Assoc., Inc., FL [SE]

Bruno Mark Wilson, Salem, OR [SE]

Charlie S. Woodard, Ft. Worth Fire Dept., TX [E]

Alternates

William Lee Bullock, Fairfax County Fire & Rescue Dept., VA [E]
(Alt. to G. P. Benarick)

Michael E. Burns, Michael E. Burns & Assoc., MD [M]
(Alt. to B. Berry)

Michael L. Donahue, Hildebrand & Noll Assoc., Inc., MD [SE]
(Alt. to G. Noll)

Leslie D. English, MacMillan Bloedel Packaging Inc., AL [U]
(Alt. to J. T. Higgins)

Brian S. Geraci, Montgomery County Dept. of Fire & Rescue Services, MD [E]
(Alt. to M. B. Michos)

Wilmuth E. Hubbs, Rhone-Poulenc, NC [M]
(Alt. to M. A. Ehrlich, Jr.)

Committee Scope: This Committee shall have primary responsibility for documents on the requirements for the professional competence, training, procedures, and equipment for emergency responders to hazardous materials incidents.

NFPA 471

Recommended Practice for

Responding to Hazardous Materials Incidents

1997 Edition

NOTICE: An asterisk (*) following the number or letter designating a paragraph indicates that explanatory material on the paragraph can be found in Appendix A.
Information on referenced publications can be found in Chapter 9 and Appendix B.

Chapter 1 Administration

1-1* Scope.

This recommended practice applies to all organizations that have responsibilities when responding to hazardous materials incidents and recommends standard operating guidelines for responding to such incidents. Planning procedures, policies, and application of procedures for incident levels, personal protective equipment, decontamination, safety, and communications are specifically covered in this recommended practice.

1-2 Purpose.

The purpose of this document is to outline the minimum requirements that should be considered when dealing with responses to hazardous materials incidents and to specify operating guidelines for responding to hazardous materials incidents. It is not the intent of this recommended practice to restrict any jurisdiction from using more stringent guidelines.

1-3 Application.

The recommendations contained in this document should be followed by organizations that respond to hazardous materials incidents and by incident commanders responsible for managing hazardous materials incidents.

1-4 Definitions.

Absorption. The process in which materials hold liquids through the process of wetting. Absorption is accompanied by an increase in the volume of the sorbate/sorbent system through the process of swelling. Some of the materials typically used as absorbents are sawdust, clays, charcoal, and polyolefin-type fibers. These materials can be used for confinement, but it should be noted that the sorbed liquid can be desorbed under mechanical or thermal stress. When absorbents become contaminated, they retain the properties of the absorbed liquid and are, therefore, considered to be hazardous materials and must be treated and disposed of accordingly. *(See* ASTM F 716*, Method of Testing Sorbent Performance of Absorbents, for further information*.*)*

Adsorption. The process in which a sorbate (hazardous liquid) interacts with a solid sorbent surface. See ASTM F 726, *Method of Testing Sorbent Performance of Adsorbents*, for further information. The principal characteristics are the following:

(a) The sorbent surface is rigid and no volume increase occurs as is the case with absorbents.

(b) The adsorption process is accompanied by heat of adsorption whereas absorption is not.

(c) Adsorption occurs only with activated surfaces, e.g., activated carbon, alumina, etc.

Authority Having Jurisdiction.* The organization, office, or individual responsible for approving equipment, an installation, or a procedure.

Confinement. Those procedures taken to keep a material, once released, in a defined or local area.

Containment. The actions taken to keep a material in its container (e.g., stop a release of the material or reduce the amount being released).

Contaminant. A hazardous material that physically remains on or in people, animals, the environment, or equipment, thereby creating a continuing risk of direct injury or a risk of exposure.

Contamination. The process of transferring a hazardous material from its source to people, animals, the environment, or equipment, which may act as a carrier.

Control. The defensive or offensive procedures, techniques, and methods used in the mitigation of a hazardous materials incident, including containment, extinguishment, and confinement.

Control Zones. The areas at a hazardous materials incident that are designated based upon safety and the degree of hazard. Many terms are used to describe the zones involved in a hazardous materials incident. For purposes of this document, these zones are defined as the hot, warm, and cold zones.

Decontamination (Contamination Reduction). The physical and/or chemical process of reducing and preventing the spread of contamination from persons and equipment used at a hazardous materials incident.

Decontamination Corridor. The area, usually located within the warm zone, where decontamination procedures take place. This area is also referred to as the "decontamination area" in other documents.

Degradation.

(a) A chemical action involving the molecular breakdown of a protective clothing material or equipment due to contact with a chemical.

(b) The molecular breakdown of the spilled or released material to render it less hazardous during control operations.

Disinfection. The process used to destroy recognized pathogenic microorganisms. Proper disinfection results in a reduction in the number of viable organisms to some acceptable level. It may not totally destroy 100 percent of the microorganisms.

Emergency. A sudden and unexpected event calling for immediate action.

Emergency Decontamination. The physical process of immediately reducing contamination of individuals in potentially life-threatening situations without the formal establishment of a contamination corridor.

Environmental Hazard. A condition capable of posing an unreasonable risk to air, water, or soil quality and to plants or wildlife.

Exposure. The process by which people, animals, the environment, and equipment are subjected to or come in contact with a hazardous material. The magnitude of exposure is dependent primarily upon the duration of exposure and the concentration of the hazardous material. This term is also used to describe a person, animal, the environment, or a piece of equipment.

Gross Decontamination. The initial phase of the decontamination process during which the amount of surface contaminant is significantly reduced. This phase can include mechanical removing and initial rinsing.

Hazard/Hazardous. Capable of posing an unreasonable risk to health, safety, or the environment; capable of causing harm.

Hazard Sector. That function within an overall incident management system that deals with the mitigation of a hazardous materials incident. It is directed by a sector officer and deals principally with the technical aspects of the incident.

Hazard Sector Officer. The person responsible for the management of the hazard sector.

Hazardous Material.* A substance (gas, liquid, or solid) capable of creating harm to people, the environment, and property. *(See specific regulatory definitions in Appendix A.)*

Incident. An emergency involving the release or potential release of a hazardous material, with or without fire.

Incident Commander. The person responsible for all decisions relating to the management of the incident. The incident commander is in charge of the incident site. This term is equivalent to the on-scene incident commander.

Incident Management System. An organized system of roles, responsibilities, and standard operating procedures used to manage and direct emergency operations. Such systems are sometimes referred to as incident command systems (ICS).

Mitigation. Actions taken to prevent or reduce product loss, human injury or death, environmental damage, and property damage due to the release or potential release of hazardous materials.

Monitoring Equipment. Instruments and devices used to identify and quantify contaminants.

National Contingency Plan.* Policies and procedures of the federal agency members of the National Oil and Hazardous Materials Response Team. This document provides guidance for responses, remedial action, enforcement, and funding mechanisms for hazardous materials incident responses.

Neutralization. The process of applying acids or bases to a corrosive product to form a neutral salt.

Penetration. The movement of a material through a suit's closures, such as zippers, buttonholes, seams, flaps, or other design features of chemical-protective clothing, and through punctures, cuts, and tears.

Permeation. A chemical action involving the movement of chemicals, on a molecular level, through intact material.

Protective Clothing. Equipment designed to protect the wearer's skin or eyes from heat and hazardous materials. Protective clothing is divided into the following three types:

(a) Chemical-protective clothing:

1. Liquid splash-protective clothing
2. Vapor-protective clothing

(b) High temperature-protective clothing

(c) Structural fire-fighting protective clothing

Response. That portion of incident management in which personnel are involved in controlling (defensively or offensively) a hazardous materials incident. The activities in the response portion of a hazardous materials incident include analyzing the incident, planning the response, implementing the planned response, and evaluating progress.

Sampling. The process of collecting a representative amount of gas, liquid, or solid for analytical purposes.

Secondary Contamination. The process by which a contaminant is carried out of the hot zone and subsequently contaminates people, animals, the environment, or equipment.

Should. Indicates a recommendation or that which is advised but not required.

Solidification. The process whereby a hazardous liquid is treated chemically so that solid material results.

Stabilization. The point in an incident at which the adverse behavior of the hazardous material is controlled.

Sterilization. The process of destroying all microorganisms in or on an object.

Waste Minimization. Treatment of hazardous spills by procedures or chemicals designed to reduce the hazardous nature of the material and to minimize the quantity of waste produced.

Chapter 2 Incident Response Planning

2-1 Developing an Incident Response Plan.

2-1.1

Planning is an essential part of emergency preparedness. The development of both facility response plans and community emergency plans is required by numerous state and federal laws, including Superfund Amendments and Reauthorization Act (SARA), Title III, "The Emergency Planning and Community Right to Know Act of 1986." Planning guides and reference materials are listed in Appendix C.

2-1.2

A planning team is necessary for developing the hazardous materials emergency plan. Local, state, and federal planning guidelines should be reviewed and consulted by the planning team when preparing plans for hazardous materials incidents.

2-2 Review and Training.

2-2.1

As a minimum, an annual review and update of the hazardous materials emergency plan should be conducted.

2-2.2

As a minimum, a training exercise should be conducted annually to determine the adequacy and effectiveness of the hazardous materials emergency plan.

Chapter 3 Response Levels

3-1* Planning Guide.

Table 3-1 is a planning guide intended to provide the user with assistance in determining incident levels for response and training. Potential applications to a jurisdiction's response activities can include development of standard operating procedures; implementation of a training program using the competency levels of NFPA 472, *Standard for Professional Competence of Responders to Hazardous Materials Incidents;* acquisition of necessary equipment; and development of community emergency response plans. When consulting this table, the user should refer to all of the incident condition criteria to determine the appropriate incident level.

Table 3-1 Planning Guide for Determining Incident Levels, Response, and Training

	Incident Level		
Incident Conditions	**One**	**Two**	**Three**
Product identifications	Placard not required, NFPA 0 or 1 all categories, all Class 9 and ORM-D	DOT placarded, NFPA 2 for any categories, PCBs without fire, EPA regulated waste	Class 2, Division 2.3 poisonous gases, Class 1, Division 1.1 and 1.2 explosives, organic peroxide, flammable solid, materials dangerous when wet, chlorine, fluorine, anhydrous ammonia, radioactive materials, NFPA 3 & 4 for any categories including special hazards, PCBs & fire, DOT inhalation hazard, EPA extremely hazardous substances, and cryogenics
Container size	Small (e.g., pail, drums, cylinders except1-ton, packages, bags)	Medium (e.g., 1-ton cylinder, portable containers, nurse tanks, multiple small packages)	Large (e.g., tank cars, tank trucks, stationary tanks, hopper cars/trucks, multiple medium containers)
Fire/explosion potential	Low	Medium	High
Leak severity	No release or small release contained or confined with readily available resources	Release may not be controllable without special resources	Release may not be controllable even with special resources
Life safety	No life-threatening situation from materials involved	Localized area, limited evacuation area	Large area, mass evacuation area
Environmental impact (potential)	Minimal	Moderate	Severe
Container integrity	Not damaged	Damaged but able to contain the contents to allow handling or transfer of product	Damaged to such an extent that catastrophic rupture is possible

Chapter 4 Site Safety

4-1 Emergency Incident Operations.

4-1.1

Emergency incident operations should be conducted in compliance with Chapter 6 of NFPA 1500, *Standard on Fire Department Occupational Safety and Health Program*, or Title 29, *Code of Federal Regulations*, Part 1910.120 or EPA.

4-1.2*

An incident management system should be implemented at all hazardous materials incidents. Operations should be directed by a designated incident commander and follow established written standard operating procedures.

4-1.2.1 Personnel Accountability. The incident management system should include a standard personnel identification system to maintain accountability for each member engaged in activities at an incident scene. This personnel identification system should have the ability to provide a rapid accounting of all members on the incident scene.

4-1.2.1.1 The personnel identification system should include a means to specifically identify and keep track of members entering and leaving the hot zone and any area where special protective equipment is required.

4-1.2.1.2 The incident management system should include a standard operating procedure to evacuate personnel from an area where an imminent hazard condition is found to exist and account for the safety of personnel. This system should include a method to immediately notify all personnel in the affected area of an imminent hazard condition by means of audible warning devices.

4-1.2.2 Rest and Rehabilitation. The incident commander should consider the circumstances of each incident and make suitable provisions for rest and rehabilitation for members operating at the scene. These considerations should include medical evaluation and treatment, food and fluid replenishment, and relief from extreme climatic conditions, according to the circumstances of the incident.

All incident commanders should maintain an awareness of the condition of members operating within their span of control and ensure that adequate steps are taken to provide for their safety and health. The command structure should be utilized to request relief and reassignment of fatigued members.

4-1.3

An emergency response plan describing the general safety procedures that are to be followed at an incident should be prepared in accordance with Title 29, *Code of Federal Regulations,* Part 1910.120. These procedures should be thoroughly reviewed and tested.

4-2 Ignition Sources.

Ignition sources should be eliminated whenever possible at incidents involving releases, or probable releases, of ignitable materials. Whenever possible, electrical devices used within the hot zone should be certified as intrinsically safe by recognized organizations.

4-3 Control Zones.

Control zone names have not been consistently applied at incidents. The intent of this section is to show areas of responder control. The various zones or areas at a typical emergency response site are shown in Figure 4-3.

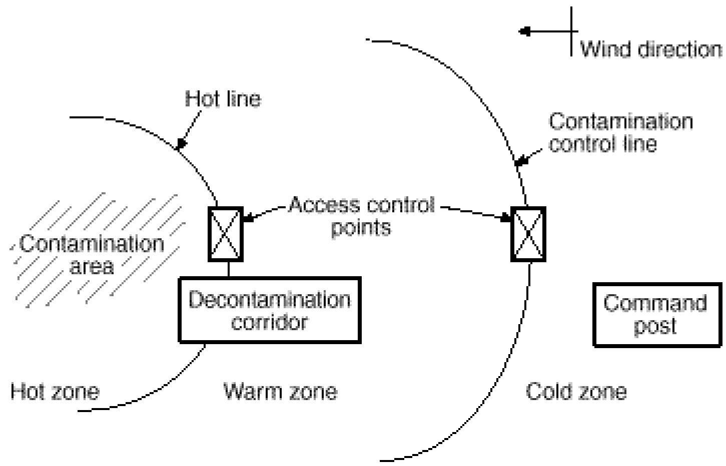


Figure 4-3 Diagram of control zones.

4-3.1* Hot Zone.

The hot zone is the area immediately surrounding a hazardous materials incident, extending far enough to prevent adverse effects from hazardous materials releases to personnel outside the zone. This zone is also referred to as the exclusion zone or restricted zone in other documents.

4-3.2 Warm Zone.

The warm zone is the area where personnel and equipment decontamination and hot zone support take place. It includes control points for the access corridor and thus assists in reducing the spread of contamination. This zone is also referred to as the decontamination, contamination reduction, or limited access zone in other documents.

4-3.3 Cold Zone.

The cold zone contains the command post and such other support functions as are deemed necessary to control the incident. This zone is also referred to as the clean zone or support zone in other documents.

4-4 Communications.

4-4.1

When personal protective clothing or remote operations inhibit communications, an effective means of communication, such as radios, should be established.

4-4.2

The frequencies employed in these radios should be “dedicated” and not used or shared with other local agencies.

4-4.3

Communication should be supplemented by a prearranged set of hand signals and hand-light signals to be used when primary communication methods fail. Hand-lights employed for this purpose should be in accordance with NFPA 70, *National Electrical Code*®, for use in hazardous environments.

4-5 Monitoring Equipment.

4-5.1

Monitoring equipment operates on several different principles and measures different aspects of hazardous materials releases. Examples of this equipment include the following:

(a) Oxygen meters

(b) Combustible gas indicator (explosimeter)

(c) Carbon monoxide meter

(d) pH meter

(e) Radiation detection instruments

(f) Colorimetric detector tubes

(g) Organic vapor analyzer

(h) Photoionization meter

(i) Air sampling devices

(j) Other meters to measure specific products such as chlorine, hydrogen sulfide, or ethylene oxide

(k) pH paper or strips

(l) Organic vapor badge or film strip

(m) Mercury badge

(n) Formaldehyde badge or strip

4-5.2

All monitoring equipment should be operationally checked prior to use and periodically calibrated in accordance with manufacturers' specifications.

Chapter 5 Personal Protective Equipment

5-1 General.

It is essential that personal protective equipment meeting appropriate NFPA and OSHA standards be provided, maintained, and used. Protection against physical, chemical, and thermal hazards should be considered when selecting personal protective equipment.

5-1.1

A written personal protective equipment program should be established in accordance with Title 29, *Code of Federal Regulations*, Part 1910.120. Elements of the program should include personal protective equipment selection and use; storage, maintenance, and inspection procedures; and training considerations. The selection of personal protective clothing should be based on the hazardous materials and conditions present and should be appropriate for the hazards encountered.

5-1.2

Protective clothing and equipment used to perform fire suppression operations, beyond the incipient stage, should meet the requirements of Chapter 5 of NFPA 1500, *Standard on Fire Department Occupational Safety and Health Program*. Structural fire-fighting protective clothing is not intended to provide chemical protection to the user.

5-2 Respiratory Protective Equipment.

5-2.1

Self-contained breathing apparatus (SCBA) should meet the requirements of NFPA 1981, *Standard on Open-Circuit Self-Contained Breathing Apparatus for Fire Fighters*.

5-2.2

Personal alert safety systems should meet the requirements of NFPA 1982, *Standard on Personal Alert Safety Systems (PASS) for Fire Fighters*.

5-2.3 Air Purifying Respirators.

These devices are worn to filter particulates and contaminants from the air. They should be worn only in atmospheres where the type and quantity of the contaminants are known and sufficient oxygen is known to be present.

5-3 Chemical-Protective Clothing.

5-3.1

Chemical-protective clothing (CPC) is made from special materials and is designed to prevent the contact of chemicals with the body. Chemical-protective clothing is of two types: totally encapsulating and nonencapsulating.

5-3.2

A variety of materials are used to make the fabric from which chemical-protective clothing is manufactured. Each material provides protection against certain specified chemicals or mixtures of chemicals but might afford little or no protection against certain other chemicals. It is most important to note that there is no material that provides satisfactory protection from all chemicals. Protective clothing material needs to be compatible with the chemical substances involved, consistent with manufacturers' instructions.

5-3.3*

Performance requirements need to be considered in selecting the appropriate chemical-protective material. These requirements would include chemical resistance, permeation, penetration, flexibility, abrasion, temperature resistance, shelf life, and sizing criteria.

5-4 Thermal Protection.

5-4.1 Proximity Suits.

These suits provide short duration and close proximity protection at radiant heat temperatures as high as 2,000ºF (1093ºC) and can withstand some exposure to water and steam. Respiratory protection needs to be provided with proximity suits.

5-4.2 Fire Entry Suits.

These suits provide protection for brief entry into a total flame environment at temperatures as high as 2,000ºF (1093ºC). They are not effective or meant to be used for rescue operations.

Respiratory protection needs to be provided with fire entry suits.

5-4.3 Overprotection Garments.

These garments are worn in conjunction with chemical-protective encapsulating suits.

5-4.3.1 Flash Cover Protective Suits. Flash cover suits are neither proximity nor fire entry suits. They provide limited overprotection against flashback only. They are worn outside of other protective suits and are used only when the risks require them.

5-4.3.2 Low Temperature Suits. Low temperature suits provide some degree of protection of the encapsulating chemical-protective clothing from contact with low temperature gases and liquids. They are worn outside of the encapsulating chemical-protective clothing and are used only when the risks require them.

5-5 Levels of Protection.

Personal protective equipment is divided into four categories based on the degree of protection afforded.

5-5.1 Level A.

A Level A equipment is to be selected when the greatest level of skin, respiratory, and eye protection is required. The following constitute Level A equipment and should be used as appropriate:

(a) Pressure-demand, full facepiece, self-contained breathing apparatus (SCBA), or pressure-demand air line respirator with escape SCBA, approved by the National Institute of Occupational Safety and Health (NIOSH)

(b) Vapor-protective suits: totally encapsulating chemical-protective suits (TECP suits) constructed of protective clothing materials that meet the following criteria:

1. Cover the wearer's torso, head, arms, and legs

2. Include boots and gloves that may either be an integral part of the suit or separate and tightly attached

3. Completely enclose the wearer by itself or in combination with the wearer's respiratory equipment, gloves, and boots

(All components of a TECP suit, such as relief valves, seams, and closure assemblies, should provide equivalent chemical resistance protection. Vapor-protective suits should meet the requirements in NFPA 1991, *Standard on Vapor-Protective Suits for Hazardous Chemical Emergencies*.)

(c) Coveralls (optional)

(d) Long underwear (optional)

(e) Gloves, outer, chemical-resistant

(f) Gloves, inner, chemical-resistant

(g) Boots, chemical-resistant, steel toe and shank

(h) Hard hat (under suit) (optional)

(i) Disposable protective suit, gloves, and boots (depending on suit construction, can be worn over totally encapsulating suit)

(j) Two-way radios (worn inside encapsulating suit)

5-5.2 Level B.

Level B personal protective equipment should be used when the highest level of respiratory protection is necessary but a lesser level of skin protection is needed. The following constitute Level B equipment and should be used as appropriate:

(a) Pressure-demand, full facepiece, self-contained breathing apparatus (SCBA), or pressure-demand air line respirator with escape SCBA, NIOSH approved

(b) Hooded chemical-resistant clothing that meets the requirements of NFPA 1992, *Standard on Liquid Splash-Protective Suits for Hazardous Chemical Emergencies* (overalls and long-sleeved jacket, coveralls, one- or two-piece chemical-splash suit, disposable chemical-resistant overalls)

(c) Coveralls (optional)

(d) Gloves, outer, chemical-resistant

(e) Gloves, inner, chemical-resistant

(f) Boots, outer, chemical-resistant, steel toe and shank

(g) Boot covers, outer, chemical-resistant (disposable) (optional)

(h) Hard hat

(i) Two-way radios (worn inside encapsulating suit)

(j) Face shield (optional)

5-5.3* Level C.

Level C personal protective equipment should be used when the concentration(s) and type(s) of airborne substance(s) is known and the criteria for using air purifying respirators are met. The following constitute Level C equipment and should be used as appropriate:

(a) Full-face or half-mask, air purifying respirators, self-contained positive pressure breathing apparatus, NIOSH approved

(b) Hooded chemical-resistant clothing that meets the requirements of NFPA 1993, *Standard on Support Function Protective Garments for Hazardous Chemical Operations* (overalls, two-piece chemical-splash suit, disposable chemical-resistant overalls)

(c) Coveralls (optional)

(d) Gloves, outer, chemical-resistant

(e) Gloves, inner, chemical-resistant

(f) Boots, outer, chemical-resistant, steel toe and shank

(g) Boot covers, outer, chemical-resistant (disposable) (optional)

(h) Hard hat

(i) Escape mask (optional)

(j) Two-way radios (worn under outside protective clothing)

(k) Face shield (optional)

5-5.4 Level D.

A work uniform affording minimal protection, Level D personal protective equipment should be used for nuisance contamination only. The following constitute Level D equipment and should be used as appropriate:

(a) Coveralls

(b) Gloves (optional)

(c) Boots/shoes, chemical-resistant, steel toe and shank

(d) Boots, outer, chemical-resistant (disposable) (optional)

(e) Safety glasses or chemical-splash goggles

(f) Hard hat

(g) Escape mask (optional)

(h) Face shield (optional)

5-6 Types of Hazards.

The types of hazards for which Levels A, B, C, and D protection are appropriate are described in this section.

5-6.1

Level A protection should be used under any of the following conditions:

(a) When the hazardous material has been identified and requires the highest level of protection for skin, eyes, and the respiratory system based on either the measured (or potential for) high concentration of atmospheric vapors, gases, or particulates; or the site operations and work functions involve a high potential for splash, immersion, or exposure to unexpected vapors, gases, or particulates of material that are harmful to skin or capable of being absorbed through the intact skin

(b) When substances with a high degree of hazard to the skin are known or suspected to be present, and skin contact is possible

(c) When operations need to be conducted in confined, poorly ventilated areas, and the absence of conditions requiring Level A has not yet been determined

5-6.2

Level B protection should be used under any of the following conditions:

(a)* When the type and atmospheric concentration of substances have been identified and require a high level of respiratory protection, but less skin protection

(b) When the atmosphere contains less than 19.5 percent oxygen

(c) When the presence of incompletely identified vapors or gases is indicated by a direct-reading organic vapor detection instrument, but the vapors and gases are known not to contain high levels of chemicals harmful to skin or capable of being absorbed through the intact skin

(d) When the presence of liquids or particulates is indicated, but they are known not to contain high levels of chemicals harmful to skin or capable of being absorbed through the intact skin

5-6.3

Level C protection should be used under any of the following conditions:

(a) When the atmospheric contaminants, liquid splashes, or other direct contact will not adversely affect or be absorbed through any exposed skin

(b) When the types of air contaminants have been identified, concentrations have been measured, and an air purifying respirator is available that can remove the contaminants

(c) When all criteria for the use of air purifying respirators are met

(d)* Atmospheric concentration of chemicals must not exceed IDLH levels. The atmosphere must contain at least 19.5 percent oxygen.

5-6.4

Level D protection should be used when both of the following conditions exist:

(a) The atmosphere contains no known hazard

(b)* Work functions preclude splashes, immersion, or the potential for unexpected inhalation of or contact with hazardous levels of any chemicals

Chapter 6 Incident Mitigation

6-1 Control.

This chapter addresses those actions necessary to ensure confinement and containment (the first line of defense) in a manner that will minimize risk to both life and the environment in the early, critical stages of a spill or leak. Both natural and synthetic methods can be employed to limit the releases of hazardous materials so that effective recovery and treatment can be accomplished with minimum additional risk to the environment or to life.

6-2 Types of Hazardous Materials.

6-2.1 Chemical Materials.

Chemical materials are those materials that pose a hazard based upon their chemical and physical properties.

6-2.2 Biological Materials.

Biological materials are those organisms that have a pathogenic effect to life and the environment and can exist in normal ambient environments.

6-2.3 Radioactive Materials.

Radioactive materials are those materials that emit ionizing radiation.

6-3 Physical States of Hazardous Materials.

Hazardous materials can be classified into three states, namely gases, solids, and liquids. They can be stored or contained at a high or low pressure. All three states can be affected by the environment in which the incident occurs. The emergency responder needs to take into account such conditions as heat, cold, rain, or wind, which can have a significant effect on the methods used to accomplish a safe operation.

6-4 Methods of Mitigation.

There are two basic methods for mitigation of hazardous materials incidents: physical and chemical. Table 6-4.1 lists many physical methods and Table 6-4.2 lists many chemical methods that are acceptable for mitigation of hazardous materials incidents. Recommended practices should be implemented only by personnel appropriately prepared by training, education, or experience.

6-4.1* Physical Methods.

Physical methods of control involve any of several processes or procedures to reduce the area of the spill, leak, or other release mechanism. In all cases, methods used should be acceptable to the incident commander. The selection of personal protective clothing should be based on the hazardous materials and/or conditions present and should be appropriate for the hazards encountered. Refer to Table 6-4.1.

Table 6-4.1 Physical Methods of Mitigation of Hazardous Materials

	Chemical				Biological				Radiological			
	Gases				Gases				Gases			
Method	**LVP***	**HVP****	**Liq.**	**Sol.**	**LVP**	**HVP**	**Liq.**	**Sol.**	**LVP**	**HVP**	**Liq.**	**Sol.**
Absorption	yes	yes	yes	no	no	no	yes[4]	no	no	no	yes	no
Covering	no	no	yes	yes	no	no	yes	yes	no	no	yes[3]	yes[3]
Dikes, dams, diversions, and retention	yes	yes[5]	yes	yes	no	no	yes	yes	no	no	yes	yes
Dilution	yes	yes	yes	yes	no	no	no	no	yes	no	yes	yes
Overpack	yes	no	yes	yes	yes	no	yes	yes	yes	no	yes	yes
Plug/patch	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Transfer	yes	no	yes	yes	yes	no	yes	yes	yes	no	yes	yes
Vapor suppression (blanketing)	no	no	yes	yes	no	no	yes	yes	no	no	no	no

Vacuuming	no	no	yes	yes	no	no	yes	yes	no	no	yes	yes
Venting[1]	yes	yes	yes	no	yes	no	no	no	yes[2]	no	no	no

NOTE: For substances involving more than one type, the most restrictive control measure should be used.
*Low Vapor Pressure
**High Vapor Pressure
1. Venting of low-vapor-pressure gases is recommended only when an understanding of the biological system is known. Venting is allowed when the bacteriological system is known to be nonpathogenic, or if methods can be employed to make the environment hostile to pathogenic bacteria.
2. Venting of low-vapor-pressure radiological gases is allowed when the gas(es) is/are known to be alpha or beta emitters with short half-lives. Further, this venting is only to be allowed after careful consultation with a certified health physicist.
3. Covering should be done only after consultation with appropriate experts.
4. Absorption of liquids containing bacteria is permitted where the absorption bacteria or environment is hostile to the bacteria.
5. Water dispersion on certain vapors and gases only.

6-4.1.1* Absorption. Absorption is the process in which materials hold liquids through the process of wetting. Absorption is accompanied by an increase in the volume of the sorbate/sorbent system through the process of swelling. Some of the materials typically used as absorbents are sawdust, clays, charcoal, and polyolefin-type fibers. These materials can be used for confinement, but it should be noted that the sorbed liquid can be desorbed under mechanical or thermal stress. When absorbents become contaminated, they retain the properties of the absorbed hazardous liquid and are, therefore, considered to be hazardous materials and must be treated and disposed of accordingly. *(See ASTM F716, Method of Testing Sorbent Performance of Absorbents, for further information.)*

6-4.1.2 Covering. Covering is a temporary form of mitigation for radioactive, biological, and some chemical substances such as magnesium. It should be done after consultation with a certified health physicist (in the case of radioactive materials) or other appropriate experts.

6-4.1.3 Dikes, Dams, Diversions, and Retention. These terms refer to the use of physical barriers to prevent or reduce the quantity of liquid flowing into the environment. Dikes or dams usually refer to concrete, earth, and other barriers temporarily or permanently constructed to hold back the spill or leak. Diversion refers to the methods used to physically change the direction of flow of the liquid. Vapors from certain materials, such as liquefied petroleum gas (LPG), can be dispersed by means of a water spray.

6-4.1.4 Dilution. Dilution is the application of water to water-miscible hazardous materials. The goal is to reduce the hazard to safe levels.

6-4.1.5 Overpacking. The most common form of overpacking is accomplished by the use of an oversized container. Overpack containers should be compatible with the hazards of the materials involved. If the material is to be shipped, DOT specification overpack containers need to be used. (The spilled materials still should be treated or properly disposed of.)

6-4.1.6 Plug and Patch. Plugging and patching is the use of compatible plugs and patches to reduce or temporarily stop the flow of materials from small holes, rips, tears, or gashes in containers. The repaired container should not be reused without proper inspection and certification.

6-4.1.7 Transfer. Transfer is the process of moving a liquid, gas, or some forms of solids, either manually, by pump, or by pressure, from a leaking or damaged container or tank. Care needs to be taken to ensure the pump, transfer hoses and fittings, and container selected are compatible with the hazardous material. When a product transfer presents fire or explosion hazard, proper concern for electrical continuity (such as bonding/grounding) needs to be observed.

6-4.1.8 Vacuuming. Many hazardous materials may be placed in containment simply by vacuuming them up. This has the advantage of not causing an increase in volume. Care needs to be taken to ensure compatibility of materials. The exhaust air can be filtered, scrubbed, or treated as needed. The method of vacuuming will depend on the nature of the hazardous material.

6-4.1.9 Vapor Dispersion. Vapors from certain materials can be dispersed or moved by means of a water spray. With other products, such as liquefied petroleum gas (LPG), the gas concentration may be reduced below the lower flammable limit through rapid mixing of the gas with air, using the turbulence created by a fine water spray. Reducing the concentration of the material through the use of water spray may bring the material into its flammable range.

6-4.1.10* Vapor Suppression (Blanketing). Vapor suppression is the reduction or elimination of vapors emanating from a spilled or released material through the most efficient method or application of specially designed agents. A recommended vapor suppression agent is an aqueous foam blanket.

6-4.1.11 Venting. Venting is a process that is used to deal with liquids or liquefied compressed gases where a danger, such as an explosion or mechanical rupture of the container or vessel, is considered likely. The method of venting will depend on the nature of the hazardous material. In general, it involves the controlled release of the material to reduce and contain the pressure and diminish the probability of an explosion.

6-4.2* Chemical Methods.

Chemical methods of control involve the application of chemicals to treat spills of hazardous materials. Chemical methods may involve any one of several actions to reduce the involved area affected by the release of a hazardous material. *(See Table 6-4.2.)* In all cases, methods used should be acceptable to the incident commander. The selection of personal protective clothing should be based on the hazardous materials and/or conditions present and should be appropriate for the hazards encountered.

Table 6-4.2 Chemical Methods of Mitigation of Hazardous Materials

	Chemical				Biological				Radiological			
	Gases				Gases				Gases			
Method	**LVP***	**HVP****	**Liq.**	**Sol.**	**LVP**	**HVP**	**Liq.**	**Sol.**	**LVP**	**HVP**	**Liq.**	**Sol**
Adsorption	yes	yes	yes	no	yes[3]	yes	yes[3]	no	no	no	no	no
Burn	yes	yes	yes	yes	yes	yes	yes	yes	no	no	no	no
Dispersion/ emulsification	no	no	yes	yes	no	no	yes[3]	no	no	no	no	no

Flare	yes	yes	yes	no	yes	yes	yes	no	no	no	no	no
Gelatin	yes	no	yes	yes	yes[3]	no	yes[3]	yes[3]	no	no	no	no
Neutralization	yes[1]	yes[4]	yes	yes[2]	no	no	no	no	no	no	no	no
Polymerization	yes	no	yes	yes	no	no	no	no	no	no	no	no
Solidification	no	no	yes	no	no	no	yes[3]	no	no	no	yes	no
Vapor suppression	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Vent/Burn	yes	yes	yes	no	yes	yes	yes	no	no	no	no	no

*Low Vapor Pressure
**High Vapor Pressure
1. Technique may be possible as a liquid or solid neutralizing agent, and water can be applied.
2. When solid neutralizing agents are used, they must be used simultaneously with water.
3. Technique is permitted only if resulting material is hostile to the bacteria.
4. The use of this procedure requires special expertise and technique.

6-4.2.1* Adsorption. Adsorption is the process in which a sorbate (hazardous liquid) interacts with a solid sorbent surface. See ASTM F 726, *Method of Testing Sorbent Performance of Adsorbents*, for further information. The principal characteristics of this interaction are the following:

(a) The sorbent surface, unlike absorbents, is rigid and no volume increase occurs.

(b) The adsorption process is accompanied by heat of adsorption whereas absorption is not.

(c) Adsorption occurs only with activated surfaces, e.g., activated carbon, alumina, etc.

6-4.2.2 Controlled Burning. For purposes of this practice, controlled combustion is considered a chemical method of control. However, it should be used only by qualified personnel trained specifically in this procedure.

In some emergency situations where extinguishing a fire will result in large, uncontained volumes of contaminated water, or threaten the safety of responders or the public, controlled burning is used as a technique. It is recommended that consultation be made with the appropriate environmental authorities when this method is used.

6-4.2.3 Dispersants, Surface Active Agents, and Biological Additives. Certain chemical and biological agents can be used to disperse or break up the materials involved in liquid spills. The use of these agents results in a lack of containment and generally results in spreading the liquid over a much larger area. Dispersants are most often applied to spills of liquids on water. The dispersant breaks down a liquid spill into many fine droplets, thereby diluting the material to acceptable levels. Use of this method may require the prior approval of the appropriate environmental authority. See ASTM STP 659, *Chemical Dispersants for the Control of Oil Spills*, and ASTM STP 840, *Oil Spill Chemical Dispersants: Research, Experience, and Recommendations*, for further information.

6-4.2.4 Flaring. Flaring is a process that is used with high-vapor-pressure liquids or liquefied compressed gases for the safe disposal of the product. Flaring is the controlled burning of material in order to reduce or control pressure and/or dispose of a product.

6-4.2.5 Gelation. Gelation is the process of forming a gel. A gel is a colloidal system consisting of two phases, a solid and a liquid. The resulting gel is considered to be a hazardous material and needs to be disposed of properly.

6-4.2.6 Neutralization. Neutralization is the process of applying acids or bases to a spill to form a neutral salt. The application of solids for neutralizing can often result in confinement of the spilled material. Special formulations are available that do not result in violent reactions or local heat generation during the neutralization process. In cases where special neutralizing formulations are not available, special considerations should be given to protecting persons applying the neutralizing agent, as heat is generated and violent reactions can occur. One of the advantages of neutralization is that a hazardous material can be rendered nonhazardous.

6-4.2.7 Polymerization. Polymerization is a process in which a hazardous material is reacted in the presence of a catalyst, in the presence of heat or light, or with itself or another material to form a polymeric system.

6-4.2.8 Solidification. Solidification is the process whereby a hazardous liquid is treated chemically so that a solid material results. Adsorbents can be considered an example of a solidification process. There are other materials that can be used to convert hazardous liquids into nonhazardous solids. Examples are applications of special formulations designed to form a neutral salt in the case of spills of acids or caustics. The advantage of the solidification process is that a spill of small scale can be confined relatively quickly and treatment effected immediately.

6-4.2.9 Vapor Suppression. Vapor suppression is the use of solid activated materials to treat hazardous materials so as to effect suppression of the vapor off-gasing from the materials. This process results in the formation of a solid that affords easier handling but that may result in a hazardous solid that must be disposed of properly.

6-4.2.10 Venting and Burning. This process involves the use of shaped charges to vent the high vapor pressure at the top of the container and then the use of additional charges to release and burn the remaining liquid in the container in a controlled fashion.

Chapter 7 Decontamination

7-1 Decontamination Plan.

At every incident involving hazardous materials, there is a possibility that personnel, their equipment, and members of the general public will become contaminated. The contaminant poses a threat, not only to the persons contaminated, but to other personnel who may subsequently come into contact with the contaminated personnel and equipment. The entire process of decontamination should be directed toward confinement of the contaminant within the hot zone and the decontamination corridor to maintain the safety and health of response personnel, the general public, and the environment. Sound judgment should be exercised and the potential effects of the decontamination process upon personnel should be considered when developing the decontamination plan.

7-1.1

Although decontamination is typically performed following site entry, the determination of proper decontamination methods and procedures needs to be considered before the incident as part of the overall pre-incident planning and hazard and risk evaluation process. No entry into the hot zone should be permitted until appropriate decontamination methods are determined and established based on the hazards present, except in those situations where a rescue may be possible and emergency decontamination is available.

7-1.2

Emergency response personnel should be familiar with the definitions of the following terminology:

(a) Contaminant

(b) Contamination

(c) Decontamination (contamination reduction)

(d) Decontamination corridor

(e) Emergency decontamination

(f) Exposure

(g) Gross decontamination

(h) Secondary contamination

7-2 Decontamination.

Decontamination consists of reducing and preventing the spread of contamination from persons and equipment used at a hazardous materials incident by physical and/or chemical processes. Emergency response personnel should implement a thorough, technically sound decontamination procedure until it is determined or judged to be no longer necessary.

7-2.1

Emergency response personnel should have an established procedure to minimize contamination or contact, to limit migration of contaminants, and to properly dispose of contaminated materials. The primary objective of decontamination is to avoid becoming contaminated or contaminating other personnel or equipment outside of the hot zone. If contamination is suspected, decontamination of personnel, equipment, and apparatus should be performed.

7-2.2

Procedures for all phases of decontamination need to be developed and implemented to reduce the possibility of contamination to personnel and equipment. Initial procedures should be upgraded or downgraded as additional information is obtained concerning the type of hazardous materials involved, the degree of hazard, and the probability of exposure of response personnel. Reference guides for the development of decontamination procedures can be found in Appendix C. Assuming protective equipment is grossly contaminated, appropriate decontamination methods should be used for the chemicals encountered.

7-2.3

The decision to implement all or part of a decontamination procedure should be based upon a field analysis of the hazards and risks involved. This analysis generally consists of referring to technical reference sources to determine the general hazards, such as flammability and toxicity, and then evaluating the relative risks. Decontamination procedures should be implemented upon arrival at the scene, should provide an adequate number of decontamination stations and personnel, and should continue until the incident commander determines that decontamination procedures are no longer required.

7-2.4 Precautionary Decontamination.

There are occasions when an apparently normal alarm response turns into a hazardous materials incident. Frequently, most of the initial assignment crews will have already gone into the incident area and exposed themselves to the contamination threat.

It is essential that all members so involved remove themselves from the area at once, call for decontamination capability, and stay together in one location. They must not wander around, climb on and off apparatus, and mix with other personnel since there is a potential for them to be contaminated.

Fire fighters so exposed should be given gross decontamination as a precautionary measure. Knowledgeable hazardous materials personnel, such as the decontamination sector officer, in conjunction with the incident commander, should determine whether more definitive decontamination is necessary.

Remember, the primary objective of decontamination is to avoid contaminating anyone or anything beyond the hot zone. When in doubt about contamination, decontaminate all involved personnel, equipment, and apparatus.

7-3 Decontamination Methods.

7-3.1 Physical Methods.

Physical methods generally involve the physical removal of the contaminant from the contaminated person or object and containment of the contaminant for appropriate disposal. While these methods can reduce the contaminant's concentration, generally the containment remains chemically unchanged. Examples of physical decontamination methods include the following:

(a) Absorption

(b) Brushing and scraping

(c) Isolation and disposal

(d) Vacuuming

(e) Washing

7-3.2 Chemical Methods.

Chemical methods are used on equipment, not people, and generally involve decontamination by changing the contaminant through some type of chemical reaction in an effort to render the contaminant less harmful. In the case of etiologic contaminants, chemical methods are actually biologically "killing" the organism. Examples of chemical methods include the following:

(a) Adsorption

(b) Chemical degradation

(c) Disinfection or sterilization

(d) Neutralization

(e) Solidification

7-3.3 Prevention Methods.

If contact with a contaminant can be controlled, the risk of exposure is reduced and the need for decontamination can be minimized. The following points should be considered to prevent contamination:

(a) Stress work practices that minimize contact with hazardous substances.

(b) Wear limited-use or disposable protective clothing and equipment, where appropriate.

7-4 Decontaminating Personal Protective Equipment (PPE).

During doffing of personal protective equipment, the clothing should be removed in a manner such that the outside surfaces do not touch or make contact with the wearer. A log of personal protective equipment used during the incident should be maintained. Personnel wearing disposable personal protective equipment should proceed through the decontamination process setup in the decontamination area, and the disposable protective equipment should be containerized and identified for disposal in accordance with established procedures.

7-4.1

The physical and chemical compatibility of decontamination solutions needs to be determined before they are used. Any decontamination method that permeates, degrades, damages, or otherwise impairs the safe function of PPE should not be used unless there are plans to isolate and dispose of the PPE.

7-4.2

Water or other solutions for washing or rinsing may have to be confined, collected, containerized, and analyzed for proper treatment and disposal. Consult with environmental and public health agencies or other appropriate reference sources and guidelines to determine the need for confinement and the appropriate disposal methods for collected decontamination fluids and personal protective equipment.

7-4.3

Decontamination methods vary in their effectiveness for removing different substances. The effectiveness of any decontamination method should be assessed throughout the decontamination operation. If decontamination does not appear to be effective, a different method should be selected and implemented. Before initiating decontamination, the following questions should be considered:

(a) Can decontamination be conducted safely?

(b) Are existing resources adequate and immediately available to perform decontamination of personnel and equipment? If not, where can they be obtained, and how long will it take to get them?

7-4.4

Criteria that can be used for evaluating decontamination effectiveness during field operations include the following:

(a) Contamination levels are reduced as personnel move through the decontamination corridor.

(b) Contamination is confined to the hot zone and decontamination corridor.

(c) Contamination is reduced to a level that is as low as reasonably achievable.

7-4.5*

Methods that may be useful in assessing the effectiveness of decontamination include the following:

(a) Visual observation (stains, discolorations, corrosive effects, etc.)

(b) Monitoring devices (Devices such as photoionization detectors (PIDs), detector tubes, radiation monitors, and pH paper strips/meters can show that contamination levels are at least below the device's detection limit.)

(c) Wipe sampling (Such sampling provides for after-the-fact information on the effectiveness of decontamination. Once a wipe swab is taken, it is analyzed by chemical means, usually in a laboratory. Both protective clothing, equipment, and skin may be tested using wipe samples.)

7-4.6*

Large items of equipment, such as vehicles and trucks, should be subjected to decontamination by washes, high-pressure washes, steam, or special solutions. Water or other solutions used for washing or rinsing may have to be confined, collected, containerized, analyzed, and treated prior to disposal. Consult with environmental and public health agencies to determine the appropriate disposition.

If a large number of vehicles need to be decontaminated, the following recommendations should be considered:

(a) Establish a decontamination pad as a primary wash station. The pad may be a coarse gravel pad, concrete slab, or a pool liner. It may be necessary to collect these decontamination fluids, and the decontamination pad may be bermed or diked with a sump or some form of water recovery system.

(b) Completely wash and rinse vehicles several times with detergent. Pay particular attention to wheel wells, radiators, engines, and chassis. Depending on the nature of the contaminant, it may be necessary to collect all runoff water from the initial gross rinse, particularly if there is contaminated mud and dirt on the underside of the chassis.

(c) Vehicles should be inspected thoroughly by qualified personnel for possible mechanical or electrical damage. Areas of concern include air intakes, filters, cooling systems, and air-operated systems.

(d) Empty completely and thoroughly wash any outside compartments that were opened. The equipment should be washed and rinsed prior to being replaced.

(e) Equipment sprayed with acids should be flushed or washed as soon as possible with a neutralizing agent such as baking soda and then flushed again with rinse water.

(f) If vehicles have been exposed to minimal contaminants such as smoke and vapors, they may be decontaminated on-site and then driven to an off-site car wash for a second, more thorough washing. Car washes may be suitable if the drainage area is fully contained and all runoff drains into a holding tank.

(g) Verification of adequacy of decontamination, where necessary, may consist of samples collected from the cab and exterior surfaces that are analyzed in an off-site laboratory.

7-4.7

Personnel assigned to the decontamination team should wear an appropriate level of personal protective equipment (PPE) and may require decontamination themselves. Personal protective equipment can be upgraded or downgraded as additional information is obtained concerning the type of hazardous materials involved, the degree of hazard, and the probability of exposure of response personnel.

7-4.8

If personnel display any symptoms of heat exhaustion or possible exposure, appropriate emergency measures need to be implemented to doff PPE, while protecting the individual from contaminants and preventing the spread of any contaminants. These individuals should be transferred to the care of emergency medical services personnel who have completed training in accordance with applicable standards (e.g., NFPA 473, *Standard for Competencies for EMS Personnel Responding to Hazardous Materials Incidents*).

7-4.9

A debriefing should be held for those involved in decontamination as soon as practical. Exposed persons should be provided with as much information as possible about the delayed health effects of the hazardous materials involved in the incident. If necessary, follow-up examinations should be scheduled with medical personnel.

7-4.10

Exposure records should be maintained for future reference by the individual's personal physician and employer.

Chapter 8 Medical Monitoring

8-1 Introduction.

8-1.1 Purpose.

The purpose of this chapter is to provide guidelines for local jurisdictions to perform medical monitoring for hazardous materials response personnel. It is not the intent of this recommended practice to restrict any jurisdiction's medical authority from using different or modified guidelines. Locally established guidelines for medical monitoring should not be negated by a decision of command personnel.

8-1.2 Definition.

Medical monitoring is the ongoing, systematic evaluation of response personnel who are at risk of suffering adverse effects of heat/cold exposure, stress, or hazardous materials exposure. This monitoring is done for the purpose of achieving early recognition and prevention of these effects in order to maintain the optimal health and safety of on-scene personnel.

8-1.3 Objectives.

Medical monitoring is performed at the site of a hazardous materials incident for the following reasons:

(a) To obtain baseline vital signs and physical assessment

(b) To identify and preclude from participation in the hot zone and warm zone activities individuals at increased risk for sustaining injury and illness as a result of on-scene activities

(c) To provide early recognition and treatment of personnel with adverse physiological responses as a result of on-scene activities

8-1.4

Pre-entry medical monitoring should be completed on all individuals wearing chemical liquid splash- and vapor-protective clothing and performing hazardous materials operations. It should be completed within one hour prior to entry.

8-2 Components of Pre-Entrance Medical Monitoring.

8-2.1 Vital Signs.

Pre-entrance medical monitoring should include the evaluation of the following vital signs:

(a) Blood pressure

(b) Pulse

(c) Respiratory rate

(d) Temperature

(e) EKG rhythm strip (10 seconds), if available

8-2.2 Skin Evaluation.

Pre-entrance medical monitoring should include an examination of the individual's skin for the following:

(a) Rashes

(b) Open sores/wounds

8-2.3 Mental Status.

The individual should be alert and oriented to time and place, have clear speech and a normal gait, and be able to respond appropriately to the situation.

8-2.4 Medical History.

A recent medical history should be obtained that includes the following:

(a) Medications, including over the counter, taken within the past 72 hours

(b) Alcohol consumption within the past 24 hours

(c) Any new medical treatment or diagnosis made within the past two weeks

(d) Symptoms of fever, nausea, vomiting, diarrhea, or cough within the past 72 hours

8-2.5 Weight.

The individual's weight should be recorded.

8-2.6 Hydration.

It should be determined whether the individual has consumed 8 - 16 ounces of water or diluted activity drink.

8-3 Exclusion Criteria.

8-3.1

The following exclusion criteria should be applied to findings of all medical monitoring completed on hazardous materials response personnel. These criteria provide the EMS Control Officer and the Hazardous Materials Branch Officer with guidelines to determine medical/physical fitness for entry.

(a) Blood pressure - diastolic greater than 105 mm Hg

(b) Pulse - greater than 70 percent maximum heart rate (220- age)

Table 8-3.1(b) Age-Predicted Heart Rates

Age	70 Percent
20 - 25	140
25 - 30	136
30 - 35	132
35 - 40	128
40 - 45	125
45 - 50	122

(c) Respiratory rate - greater than 24 per minute

(d) Temperature - greater than 99.5ºF (oral) or greater than 100.5ºF (core) or less than 97.0 ºF (oral) or less than 98.0ºF (core)

(e) Weight - no pre-entry exclusion

(f) EKG - dysrhythmia not previously detected (must be cleared by medical control)

(g) Skin evaluation - open sores, large area of rash or significant sunburn

(h) Mental status - altered mental status (i.e., slurred speech, clumsiness, weakness)

(i) Recent medical history:

1. Presence of nausea, vomiting, diarrhea, fever, upper respiratory infection, heat illness, or

heavy alcohol intake within past 72 hours, all of which contribute to dehydration

2. New prescription medications taken within past two weeks or over the counter medications such as cold, flu, or allergy medicines, taken within past 72 hours (must be cleared through local medical control or hazardous materials medical director)

3. Any alcohol within past six hours

4. Pregnancy

8-4 Components of Medical Monitoring During Entry.

8-4.1

Changes in gait, speech, or behavior that require entry personnel to undergo immediate decontamination, doffing of protective clothing, and assessment should be monitored.

8-4.2

If entry personnel complain of chest pain, dizziness, shortness of breath, weakness, nausea, or headache, they should undergo immediate decontamination, doffing of protective clothing, and assessment.

8-5 Post-Entry Medical Monitoring.

8-5.1 Objectives.

Post-entry medical monitoring is performed to determine the following:

(a) Whether an individual has suffered any immediate effects from exposure to a hazardous material or the environment

(b) An individual's health status for future assignment during or following incident (This assessment should include both physiological and psychological considerations.)

8-5.2

Components of post-entry medical monitoring should include the following:

(a) History - any symptom of hazardous material exposure, environmental exposure, or cardiovascular collapse

(b) Vital signs:

1. Blood pressure

2. Pulse

3. Respiratory rate

4. Temperature

5. EKG (if available)

(c) Weight

(d) Skin evaluation

(e) Mental status

8-6 Post-Medical Monitoring Follow-Up.

8-6.1

Post-medical monitoring follow-up should include the following:

(a) Repeat monitoring of vital signs every 5 - 10 minutes until they return to less than 85 percent of maximum pulse rate. If at 10 minutes the signs have not returned to within 10 percent of baseline, perform orthostatic vital signs.

(b) Determine from medical control what information regarding latent reactions/symptoms should be communicated to response personnel.

(c) If any of the following symptoms are present, contact medical control for direction and preparation for possible transport to a medical facility:

1. Body weight loss of greater than 3 percent or positive orthostatic (pulse increase by 20 beats per minute or systolic blood pressure decrease by 20 mm of Hg at two minutes standing)

2. Greater than 85 percent maximum pulse at 10 minutes

3. Temperature greater than 101ºF (oral) or 102ºF (core)

4. Nausea, vomiting, diarrhea, altered mental status, or respiratory, cardiac, or dermatologic complaints

8-7 Treatment Protocol for Hazardous Materials Team Members.

8-7.1

Rest time for all personnel should equal at least minimum suit time. Individuals may require additional time for oral rehydration. All personnel should be informed of signs and symptoms to watch for.

8-7.2

If the team member is not within 10 percent of baseline within 10 minutes, orthostatic vital signs should be taken.

8-7.3

If personnel experience greater than 3 percent body weight loss (4 $^1/_2$ pounds in a 150-pound person); positive orthostatic (pulse increases by 20 beats per minute or systolic blood pressure decreases by 20 mm of Hg at two minutes standing); greater than 85 percent of maximum pulse at 10 minutes; temperature greater than 101ºF oral (102º F core); nausea, altered mental status, or any other symptoms, the following treatment should be performed:

(a) Intravenous fluids hydration with Ringers Lactate or Normal Saline at rate (usually wide open) to get pulse less than 100 beats per minute, systolic blood pressure greater than 110 mm of Hg

(b) Administration of oxygen 4 L to 6 L per minute via nasal cannula, may increase as needed

(c) Consultation of reference protocols or medical control for treatment of specific symptoms/types of exposure

Chapter 9 Referenced Publications

9-1

The following documents or portions thereof are referenced within this recommended practice and should be considered as part of its recommendations. The edition indicated for each referenced document is the current edition as of the date of the NFPA issuance of this recommended practice. Some of these documents might also be referenced in this recommended practice for specific informational purposes and, therefore, are also listed in Appendix B.

9-1.1 NFPA Publications.

National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.

NFPA 70, *National Electrical Code,* 1996 edition.

NFPA 472, *Standard for Professional Competence of Responders to Hazardous Materials Incidents,* 1997 edition.

NFPA 473, *Standard for Competencies for EMS Personnel Responding to Hazardous Materials Incidents,* 1997 edition.

NFPA 1500, *Standard on Fire Department Occupational Safety and Health Program,* 1992 edition.

NFPA 1981, *Standard on Open-Circuit Self-Contained Breathing Apparatus for Fire Fighters,* 1992 edition.

NFPA 1982, *Standard on Personal Alert Safety Systems (PASS) for Fire Fighters,* 1993 edition.

NFPA 1991, *Standard on Vapor-Protective Suits for Hazardous Chemical Emergencies,* 1994 edition.

NFPA 1992, *Standard on Liquid Splash-Protective Suits for Hazardous Chemical Emergencies,* 1994 edition.

NFPA 1993, *Standard on Support Function Protective Clothing for Hazardous Chemical Operations,* 1994 edition.

9-1.2 Other Publications.

9-1.2.1 ASTM Publications. American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103-1187.

ASTM F 716, *Method of Testing Sorbent Performance of Absorbents,* 1982.

ASTM F 726, *Method of Testing Sorbent Performance of Adsorbents,* 1981.

ASTM STP 659, *Chemical Dispersants for the Control of Oil Spills.*

ASTM STP 840, *Oil Spill Chemical Dispersants: Research, Experience, and Recommendations.*

9-1.2.2 U.S. Government Publication. U.S. Government Printing Office, Superintendent of Documents, Washington, DC 20402.

Title 29, *Code of Federal Regulations,* Part 1910.120.

Appendix A Explanatory Material

This appendix is not a part of the recommendations of this NFPA document but is included for informational purposes only.

A-1-1 Many of the recommendations in this document are based on U.S. federal laws and regulations that were in effect at the time of adoption. Users should carefully review laws and regulations that may have been added or amended or that may be required by other authorities. Users outside the jurisdiction of the United States should determine what requirements may be in force at the time of application of this document.

A-1-4 Authority Having Jurisdiction. The phrase "authority having jurisdiction" is used in NFPA documents in a broad manner, since jurisdictions and approval agencies vary, as do their responsibilities. Where public safety is primary, the authority having jurisdiction may be a federal, state, local, or other regional department or individual such as a fire chief; fire marshal; chief of a fire prevention bureau, labor department, or health department; building official; electrical inspector; or others having statutory authority. For insurance purposes, an insurance inspection department, rating bureau, or other insurance company representative may be the authority having jurisdiction. In many circumstances, the property owner or his or her designated agent assumes the role of the authority having jurisdiction; at government installations, the commanding officer or departmental official may be the authority having jurisdiction.

A-1-4 Hazardous Material. There are many definitions and descriptive names being used for the term hazardous material, each of which depends on the nature of the problem being addressed.

Unfortunately, there is no one list or definition that covers everything. The U.S. agencies involved, as well as state and local governments, have different purposes for regulating hazardous materials that, under certain circumstances, pose a risk to the public or the environment.

Hazardous Materials. The U.S. Department of Transportation (DOT) uses the term *hazardous materials* to cover 11 hazard classes, some of which have subcategories called divisions. DOT includes in its regulations hazardous substances and hazardous wastes as Class 9 (Miscellaneous Hazardous Materials) both of which are regulated by the U.S. Environmental Protection Agency (EPA), if their inherent properties would not otherwise be covered.

Hazardous Substances. EPA uses the term *hazardous substances* for the chemicals that, if released into the environment above a certain amount, must be reported, and, depending on the threat to the environment, federal involvement in handling the incident can be authorized. A list of the hazardous substances is published in Title 40, *Code of Federal Regulations,* Part 302, Table 302.4. The U.S. Occupational Safety and Health Administration (OSHA) uses the term *hazardous substance* in Title 29, *Code of Federal Regulations*, Part 1910.120, which resulted from Title I of Superfund Amendments and Reauthorization Act (SARA) and covers emergency response. OSHA uses the term differently than EPA. Hazardous substances, as used by OSHA, cover every chemical regulated by both DOT and EPA.

Extremely Hazardous Substances. EPA uses the term *extremely hazardous substances* for chemicals that must be reported to the appropriate authorities if released above the threshold reporting quantity. Each substance has a threshold reporting quantity. The list of extremely hazardous substances is identified in Title III of SARA of 1986 (Title 40, *Code of Federal Regulations*, Part 355).

Toxic Chemicals. EPA uses the term *toxic chemicals* for chemicals whose total emissions or releases must be reported annually by owners and operators of certain facilities that manufacture, process, or otherwise use a listed toxic chemical. The list of toxic chemicals is identified in Title III of SARA.

Hazardous Wastes. EPA uses the term *hazardous wastes* for chemicals that are regulated under the Resource, Conservation, and Recovery Act (Title 40, *Code of Federal Regulations*, Part 261.33). Hazardous wastes in transportation are regulated by DOT (Title 49, *Code of Federal Regulations*, Parts 170-179).

Hazardous Chemicals. OSHA uses the term *hazardous chemicals* to denote any chemical that would be a risk to employees if exposed in the workplace. Hazardous chemicals cover a broader group of chemicals than the other chemical lists.

Dangerous Goods. In Canadian transportation, hazardous materials are called dangerous goods.

Class 1 (Explosives)

An explosive is any substance or article, including a device, that is designed to function by explosion (i.e., an extremely rapid release of gas and heat) or that, by chemical reaction within itself, is able to function in a similar manner even if not designed to function by explosion. Explosives in Class 1 are divided into six divisions. Each division will have a letter designation.

Division 1.1 consists of explosives that have a mass explosion hazard. A mass explosion is one that affects almost the entire load instantaneously.

Examples of Division 1.1 explosives include black powder, dynamite, and TNT.

Division 1.2 consists of explosives that have a projection hazard but not a mass explosion hazard.

Examples of Division 1.2 explosives include aerial flares, detonating cord, and power device cartridges.

Division 1.3 consists of explosives that have a fire hazard and either a minor blast hazard or a minor projection hazard or both, but not a mass explosion hazard.

Examples of Division 1.3 explosives include liquid-fueled rocket motors and propellant explosives.

Division 1.4 consists of explosive devices that present a minor explosion hazard. No device in the division may contain more than 25 g (0.9 oz) of a detonating material. The explosive effects are largely confined to the package and no projection of fragments of appreciable size or range are expected. An external fire must not cause virtually instantaneous explosion of almost the entire contents of the package.

Examples of Division 1.4 explosives include line-throwing rockets, practice ammunition, and signal cartridges.

Division 1.5 consists of very insensitive explosives. This division is comprised of substances that have a mass explosion hazard but are so insensitive that there is very little probability of initiation or of transition from burning to detonation under normal conditions of transport.

Examples of Division 1.5 explosives include prilled ammonium nitrate fertilizer-fuel oil mixtures (blasting agents).

Division 1.6 consists of extremely insensitive articles that do not have a mass explosive hazard. This division is comprised of articles that contain only extremely insensitive detonating substances and that demonstrate a negligible probability of accidental initiation or propagation.

Class 2 (Gases)

Division 2.1 (flammable gas) consists of any material that is a gas at 20ºC (68ºF) or less and 101.3 kPa (14.7 psi) of pressure, a material that has a boiling point of 20ºC (68ºF) or less at 101.3 kPa (14.7 psi), and that

(a) Is ignitable at 101.3 kPa (14.7 psi) when in a mixture of 13 percent or less by volume with air

(b) Has a flammable range at 101.3 kPa (14.7 psi) with air of at least 12 percent regardless of the lower limit

Examples of Division 2.1 gases include inhibited butadienes, methyl chloride, and propane.

Division 2.2 (nonflammable, nonpoisonous compressed gas, including compressed gas, liquefied gas, pressurized cryogenic gas, and compressed gas in solution) consists of any material (or mixture) that exerts in the packaging an absolute pressure of 280 kPa (41 psia) at 20ºC (68ºF).

A cryogenic liquid is a refrigerated liquefied gas having a boiling point colder than - 90ºC (-130ºF) at 101.3 kPa (14.7 psi) absolute.

Examples of Division 2.2 gases include anhydrous ammonia, cryogenic argon, carbon dioxide, and compressed nitrogen.

Division 2.3 (poisonous gas) consists of a material that is a gas at 20ºC (68ºF) or less and a pressure of 101.3 kPa (14.7 psi or 1 atm), a material that has a boiling point of 20ºC (68ºF) or less at 101.3 kPa (14.7 psi), and that

(a) Is known to be so toxic to humans as to pose a hazard to health during transportation

(b) In the absence of adequate data on human toxicity, is presumed to be toxic to humans because, when tested on laboratory animals, it has an LC_{50} value of not more than 5,000 ppm

Examples of Division 2.3 gases include anhydrous hydrogen fluoride, arsine, chlorine, and methyl bromide.

Hazard zones associated with Division 2.3 materials are the following:

Hazard zone A — LC_{50} less than or equal to 200 ppm

Hazard zone B — LC_{50} greater than 200 ppm and less than or equal to 1,000 ppm

Hazard zone C — LC_{50} greater than 1,000 ppm and less than or equal to 3,000 ppm

Hazard zone D — LC_{50} greater than 3,000 ppm and less than or equal to 5,000 ppm

Class 3 (Flammable Liquid)

Flammable liquid is any liquid having a flash point of not more than 60.5ºC (141ºF).

Examples of Class 3 liquids include acetone, amyl acetate, gasoline, methyl alcohol, and toluene.

Hazard zones associated with Class 3 materials are the following:

Hazard zone A — LC_{50} less than or equal to 200 ppm

Hazard zone B — LC_{50} greater than 200 ppm and less than or equal to 1,000 ppm

Combustible Liquid

Combustible liquid is any liquid that does not meet the definition of any other hazard class and has a flash point above 60ºC (140ºF) and below 93ºC (200ºF). Flammable liquids with a flash point above 38ºC (100ºF) may be reclassified as a combustible liquid.

Examples of combustible liquids include mineral oil, peanut oil, and No. 6 fuel oil.

Class 4 (Flammable Solids)

Division 4.1 (flammable solid) consists of any of the following three types of materials:

(a) Wetted explosives — explosives wetted with sufficient water, alcohol, or plasticizers to suppress explosive properties

(b) Self-reactive materials — materials that are liable to undergo, at normal or elevated temperatures, a strongly exothermic decomposition caused by excessively high transport temperatures or by contamination

(c) Readily combustible solids — solids that may cause a fire through friction and any metal powders that can be ignited

Examples of Division 4.1 materials include magnesium (pellets, turnings, or ribbons) and nitrocellulose.

Division 4.2 (spontaneously combustible material) consists of any of the following materials:

(a) Pyrophoric material — a liquid or solid that, even in small quantities and without an external ignition source, can ignite within 5 minutes after coming in contact with air

(b) Self-heating material — a material that, when in contact with air and without an energy supply, is liable to self-heat

Examples of Division 4.2 materials include aluminum alkyls, charcoal briquettes, magnesium alkyls, and phosphorus.

Division 4.3 (dangerous when wet material) consists of materials that, by contact with water, are liable to become spontaneously flammable or to give off flammable or toxic gas at a rate greater than 1 L/kg of the material per hour.

Examples of Division 4.3 materials include calcium carbide, magnesium powder, potassium metal alloys, and sodium hydride.

Class 5 (Oxidizers and Organic Peroxides)

Division 5.1 (oxidizer) consists of materials that can, generally by yielding oxygen, cause or enhance the combustion of other materials.

Examples of Division 5.1 materials include ammonium nitrate, bromine trifluoride, and calcium hypochlorite.

Division 5.2 (organic peroxide) consists of any organic compound containing oxygen (O) in the bivalent -O-O- structure that may be considered a derivative of hydrogen peroxide, where one or more of the hydrogen atoms have been replaced by organic radicals.

Division 5.2 (organic peroxide) materials are assigned to one of the following seven types:

Type A — organic peroxide that can detonate or deflagrate rapidly as packaged for transport. Transportation of Type A organic peroxides is forbidden.

Type B — organic peroxide that neither detonates nor deflagrates rapidly, but that can undergo a thermal explosion.

Type C — organic peroxide that neither detonates nor deflagrates rapidly and cannot undergo a thermal explosion.

Type D — organic peroxide that detonates only partially or deflagrates slowly, with medium to no effect when heated under confinement.

Type E — organic peroxide that neither detonates nor deflagrates and shows low, or no, effect when heated under confinement.

Type F — organic peroxide that will not detonate, does not deflagrate, shows only a low, or no, effect if heated when confined, and has low, or no, explosive power.

Type G — organic peroxide that will not detonate, does not deflagrate, shows no effect if heated when confined, and has no explosive power, is thermally stable, and is desensitized.

Examples of Division 5.2 materials include dibenzoyl peroxide, methyl, ethyl ketone peroxide, and peroxyacetic acid.

Class 6 (Poisonous Materials)

Division 6.1 (poisonous material) consists of materials, other than gases, that either are known to be so toxic to humans as to afford a hazard to health during transportation, or in the absence of adequate data on human toxicity, are presumed to be toxic to humans, including materials that cause irritation.

Examples of Division 6.1 materials include aniline, arsenic compounds, carbon tetrachloride, hydrocyanic acid, and tear gas.

Division 6.2 (infectious substance) consists of viable microorganisms, or their toxin, that cause or may cause disease in humans or animals. Infectious substance and etiologic agent are synonymous.

Examples of Division 6.2 materials include anthrax, botulism, rabies, and tetanus.

Class 7 (Radioactive Materials)

Radioactive material is any material having a specific activity greater than 0.002 microcuries per gram (μCi/g).

Examples of Class 7 materials include cobalt, uranium hexafluoride, and “yellow cake.”

Class 8 (Corrosive Materials)

Corrosive material is a liquid or solid that causes visible destruction or irreversible alterations in human skin tissue at the site of contact, or a liquid that has a severe corrosion rate on steel or aluminum.

Examples of Class 8 materials include nitric acid, phosphorus trichloride, sodium hydroxide, and sulfuric acid.

Class 9 (Miscellaneous)

Miscellaneous hazardous material is a material that presents a hazard during transport, but that is not included in another hazard class, including the following:

(a) Any material that has an anesthetic, noxious, or other similar property that could cause extreme annoyance or discomfort to a flight crew member so as to prevent the correct performance of assigned duties

(b) Any material that is not included in any other hazard class, but is subject to the DOT requirements (a hazardous substance or a hazardous waste)

Examples of Class 9 materials include adipic acid, hazardous substances (e.g., PCBs), and molten sulfur.

ORM-D Material

An ORM-D material is a material that presents a limited hazard during transportation due to its form, quantity, and packaging.

Examples of ORM-D materials include consumer commodities and small arms ammunition.

Forbidden

Forbidden is defined as prohibited from being offered or accepted for transportation. Prohibition does not apply if these materials are diluted, stabilized, or incorporated in devices.

A-1-4 National Contingency Plan. See Title 40, *Code of Federal Regulations*, Part 300, Subchapters A through J.

A-3-1 These incidents can be considered as requiring either offensive operations or defensive operations.

Offensive operations include actions taken by a hazardous materials responder, in appropriate chemical-protective clothing, to handle an incident in such a manner that contact with the released material may result. These actions include patching or plugging to slow or stop a leak; containing a material in its own package or container; and cleanup operations that may require overpacking or transfer of a product to another container.

Defensive operations include actions taken during an incident where there is no intentional contact with the material involved. These actions include elimination of ignition sources, vapor suppression, and diking or diverting to keep a release in a confined area. Defensive operations require notification and possible evacuation, but does not involve plugging, patching, or cleanup of spilled or leaking materials.

Jurisdictions have the responsibility to develop standard operating procedures that equate levels of response to levels of training indicated in NFPA 472, *Standard for Professional Competence of Responders to Hazardous Materials Incidents*. Depending on the capabilities and training of personnel, the first responder operational level may equate to incident level one and the technician level may equate to incident level two.

Response personnel should operate only at that incident level that matches their knowledge, training, and equipment. If conditions indicate a need for a higher response level, then additional personnel, appropriate training, and equipment should be summoned.

A-4-1.2 Although Title 29, *Code of Federal Regulations*, Part 1910.120 is cited in the text, it should be understood that some states will adopt these regulations under state OSHA plans and others will adopt these regulations through adoption of a similar regulation established by EPA and appropriate state agencies.

A-4-3.1 Access into the hot zone is to be limited to those persons necessary to control the incident. A log is to be maintained at the access control point to record entry and exit time of all personnel in the hot zone.

A-5-3.3 Chemical resistance is the ability of the material from which the protective garment is made to prevent or reduce degradation and permeation of the fabric by the attack chemical. Degradation is a chemical action involving the molecular breakdown of the material due to contact with a chemical. The action may cause the fabric to swell, shrink, blister, or discolor; become brittle, sticky, or soft; or deteriorate. These changes permit chemicals to penetrate the suit more rapidly or increase the probability of permeation.

Permeation is a chemical action involving the movement of chemicals, on a molecular level, through intact material. There is usually no indication that this process is occurring. Permeation is defined by two terms, permeation rate and breakthrough time. Permeation rate is the quantity of chemical that will move through an area of protective garment in a given period of time, usually expressed as micrograms of chemical per square centimeter per minute. Breakthrough time is the time required for the chemical to be measured on the inside surface of the fabric. The most desirable protective fabric is one that has the longest breakthrough time and a very low permeation rate. Breakthrough times and permeation rates are not available for all the common suit materials and the variety of chemicals that exist. Manufacturers' data and reference sources should be consulted. Generally, if a material degrades rapidly, permeation will occur rapidly.

Penetration is the movement of material through a suit's closures, such as zippers, buttonholes, seams, flaps, or other design features. Torn or ripped suits will also allow penetration.

A-5-5.3 Refer to OSHA Title 29, *Code of Federal Regulations*, Part 1910.134.

A-5-6.2(a) This situation involves atmospheres with IDLH (immediately dangerous to life and health) concentrations of specific substances that do not represent a severe skin hazard or that do not meet the criteria for use of air purifying respirators.

A-5-6.3(d) Refer to OSHA Title 29, *Code of Federal Regulations*, Part 1910.134.

A-5-6.4(b) Combinations of personal protective equipment other than those described for Levels A, B, C, and D protection may be more appropriate and may be used to provide the proper level of protection.

A-6-4.1 Procedures described in 6-4.1.1 through 6-4.1.11 should be completed only by personnel trained in those procedures.

A-6-4.1.1 Absorbents saturated with volatile liquid chemicals can create a more severe vapor hazard than the spill alone because of severely enlarged surface area for vapor release.

A-6-4.1.10 One technique available for handling a spill of a hazardous liquid is the application of foams to suppress the vapor emanating from the liquid. This technique is ideally suited for liquid spills that are contained, i.e., diked. It can also be used where the spill is not confined. In all cases this technique should be undertaken only by personnel who have been trained in the use of foam concentrate for vapor suppression. Training in the use of foam as a fire extinguishing agent is not sufficient to qualify an individual for applying foam application as a vapor-suppressing agent.

Vapor-suppressing foam concentrates vary in their effectiveness depending on a number of factors. These factors can include the type of foam, the 25 percent drainage time of the foam, the rate of application of the foam, and the depth of the foam blanket. These variables serve to emphasize the need for training of the person selecting this technique for applying foam as a vapor-suppressing medium.

Foams are produced by mechanically mixing a dilute solution of the foam concentrate and water with air, producing an expanded foam. Foams have been developed basically as fire extinguishing agents. Data have also been developed on their capability to suppress vapor release from water-immiscible flammable or combustible hydrocarbon liquids.

Foam and specific foam concentrates for each category, along with the definitions of appropriate terms, can be obtained by consulting NFPA 11, *Standard for Low-Expansion Foam;* NFPA 11A, *Standard for Medium- and High-Expansion Foam Systems;* NFPA 16, *Standard for the Installation of Deluge Foam-Water Sprinklers and Foam-Water Spray Systems;* and ASTM Standard Guide F 1129, *Using Aqueous Foams to Control the Vapor Hazard from Immiscible Volatile Liquids*.

The use of fire-fighting foam as a vapor suppressant involves some considerations that are different from those required for fire-extinguishing agents. It should be noted that fire-fighting foams are predominantly restricted to use on water-immiscible hydrocarbon liquids or polar compounds. They are not usually effective on inorganic acids or bases, nor on liquefied gases, including the hydrocarbon gases such as methane and propane, in controlling vapor release. One of the obvious issues of concern is the stability of the foam blanket as a function of time. This can be approached by looking at what is referred to as the foam quality.

Foam quality is generally measured in terms of foam expansion ratio and foam 25 percent drainage time. Foam expansion ratio refers to the volume of foam solution. AFFF is often used in nonaspirating equipment such as water fog nozzles. Nonaspirated AFFF solutions have significantly limited effectiveness in comparison with aspirated foam solutions in vapor suppression.

The 25 percent drainage time is that time which is required for 25 percent of the foam solution to drain from the foam. This is the property that is generally used to measure the stability of the foam. The slower the drainage of any expanded foam, regardless of expansion, the more effective and longer lasting is the foam blanket. This formula assumes weather conditions are ideal.

An important factor is the vapor pressure of the liquid that is being suppressed. Liquid vapor pressures can vary widely. The higher the vapor pressure, the slower the control time. The key to effective use of foam as a vapor-suppressing agent is to have a continuous foam blanket on the fuel surface. Films from AFFF/FFFP are no guarantee of effective vapor control.

It is important to recognize that there are some limitations in the use of foam fire extinguishing agents in vapor suppression. As indicated, these materials are basically designed for flammable hydrocarbon liquids. They have severe shortcomings for inorganic acids or bases or liquefied gases. They should not be used for vapor suppression of these categories of volatile hazardous chemicals without consultation with the manufacturer of the specific foam agent being considered.

Most fire-fighting foam concentrates have a limited range of pH tolerance. The pH is a measure of the acidity or alkalinity of inorganic acids or bases. The pH tolerance is the level that the bubble wall of the foam can tolerate before collapsing catastrophically. A few surfactant foams and the polar compound-type foams have good pH tolerance. Most of the protein, fluoroprotein, AFFFs, and high-expansion foams are not suitable for inorganic acids or bases.

Liquefied gas spills may be controlled by the application of high-expansion foam blankets. Low-expansion foams are not effective for liquefied gas spill control. Because of the large temperature differential between the liquefied gas and the foam, the drainage from the foam initially exaggerates boiloff from the spill. The higher the expansion, the lesser the effect of the drainage. For liquefied gases and all water-reactive inorganic materials, the foam should exhibit the best chemical resistance and expansion ratios to ensure maximum water retention consistent with the condition of the spill site. Since each spilled material can have unique properties, the manufacturer of the foam concentrate should be consulted for directions.

The great differences in the chemistry of flammable hydrocarbon liquids and the water-reactive inorganic materials have resulted in the development of foam concentrates specifically applicable to the inorganic chemicals. Few fire fighting foams have capabilities of vapor suppression of the inorganic acids and bases. For effective control, special foam concentrates should be employed.

Some special foam concentrates are specific for either acids or alkalis but not both. Further, they are not applicable to all inorganic materials, nor are they effective in fire suppression. In many cases, their effectiveness is limited, and intermittent foam make-up may be required to maintain the foam blanket. Others, usually containing a polymer modification, can cover a wide range of materials, both acids and bases, and may possess some degree of fire resistance. This is important for those inorganic materials that may also pose a fire hazard.

At present, there is no single foam concentrate that is truly effective against all categories of volatile hazardous chemicals. A few possess limited capabilities in most categories, but they are compromise materials, sacrificing in one category to provide some capability in other categories. These may, however, be the best choice for first responders where an overall capability is essential.

In all cases, however, the foam manufacturer or the manufacturer's literature should be consulted to provide specific guidance for the chemical to be treated.

Vapor suppression can also be considered a chemical method of mitigation.

A-6-4.2 The procedures described in 6-4.2.1 through 6-4.2.10 should be used only by personnel trained in those procedures.

A-6-4.2.1 Spontaneous ignition can occur through the heat of adsorption of flammable materials and caution should be exercised.

Adsorbents saturated with volatile liquid chemicals can create a more severe vapor hazard than the spill alone because of the severely enlarged surface area for vapor release.

A-7-4.5 It should be noted that for etiologic hazards and many chemical hazards, there is no real-time way to determine the effectiveness of decontamination in the field.

A-7-4.6 Additional information can be found in NFPA 472, *Standard for Professional Competence of Responders to Hazardous Materials Incidents,* A-15-2.3.4.5

Appendix B Referenced Publications

B-1 The following documents or portions thereof are referenced within this recommended practice for informational purposes only and are thus not considered part of its recommendations. The edition indicated here for each reference is the current edition as of the date of the NFPA issuance of this recommended practice.

B-1.1 NFPA Publications. National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.

NFPA 11, *Standard for Low-Expansion Foam*, 1994 edition.

NFPA 11A, *Standard for Medium- and High-Expansion Foam Systems*, 1994 edition.

NFPA 16, *Standard for the Installation of Deluge Foam-Water Sprinkler and Foam-Water Spray Systems*, 1995 edition.

NFPA 472, *Standard for Professional Competence of Responders to Hazardous Materials Incidents*, 1997 edition.

B-1.2 Other Publications.

B-1.2.1 ASTM Publication. American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959.

ASTM F 1129, *Using Aqueous Foams to Control the Vapor Hazard from Immiscible Volatile Liquids*, 1988.

B-1.2.2 U.S. Government Publications. U.S. Government Printing Office, Superintendent of Documents, Washington, DC 20402.

Title 29, *Code of Federal Regulations*, Parts 1910.120, 1910.134

Title 40, *Code of Federal Regulations*, Parts 261.33, 300, 302, and 355

Title 49, *Code of Federal Regulations*, Parts 170-179.

Appendix C Suggested Reading List

This appendix is not a part of the recommendations of this NFPA document but is included for informational purposes only.

C-1 Introduction.

This list provides the titles of references and organizations that may be of value to those responding to hazardous materials incidents. This list can be expanded based on personal preferences and requirements.

The references are categorized by subject. The title, author, publisher, and place of publication are given for each. The year of publication is not always given because many are revised annually. The user should attempt to obtain the most recent edition.

The last section lists sources of these references as well as other information that might be useful. Usually, these agencies or associations will provide a catalog on request. Where available, phone numbers are also listed.

C-2 References.

C-2.1 Industrial Hygiene (Air Sampling and Monitoring, Respiratory Protection, Toxicology).

Air Sampling Instruments for Evaluation of Atmospheric Contaminants, American Conference of Governmental Industrial Hygienists, Cincinnati, OH, 8th edition, 1995.

Fundamentals of Industrial Hygiene, National Safety Council, Chicago, IL, 4th edition, 1996.

Patty's Industrial Hygiene and Toxicology, John Wiley and Sons, Inc., New York, NY, 4th edition, 1995.

NIOSH Pocket Guide to Chemical Hazards, DHHS No. 85-114, NIOSH, Department of Health and Human Services, Cincinnati, OH, 1995.

Occupational Health Guidelines for Chemical Hazards, DHHS No. 81-123, NIOSH, Department of Health and Human Services, Cincinnati, OH.

Occupational Safety and Health Standards, Title 29, *Code of Federal Regulations,* Part 1910.120, “Hazardous Waste Operations and Emergency Response Final Rule,” U.S. Government Printing Office, Washington, DC.

Documentation of Threshold Limit Values and Biological Exposure Indices, American Conference of Governmental Industrial Hygienists, Cincinnati, OH, 6th edition, 1991.

C-2.2 Chemical Data.

Chemical Hazard Response Information System (CHRIS), U.S. Coast Guard, Washington, DC, Commandant Instruction M.16565.12A.

CHRIS — A Condensed Guide to Chemical Hazards, U.S. Coast Guard, Commandant Instruction M.16565.11a.

Hawley Condensed Chemical Dictionary, Van Nostrand Reinhold Co., New York, NY, 12th edition, 1993.

Dangerous Properties of Industrial Materials, N. Irving Sax, Van Nostrand Reinhold Co., New York, NY, 9th edition, 1996.

Effects of Exposure to Toxic Gases, Matheson, 3rd edition, 1988.

Emergency Handling of Hazardous Materials in Surface Transportation, Association of American Railroads, Washington, DC, 1992.

Farm Chemicals Handbook, Farm Chemicals Magazine, Willoughby, OH.

Firefighter’s Handbook of Hazardous Materials, Baker, Charles J., Maltese Enterprises, Indianapolis, IN, 5th edition, 1990.

Fire Protection Guide to Hazardous Materials, National Fire Protection Association, Quincy, MA, 11th edition, 1996.

The Merck Index, Whitehouse Station, NJ: Merck, 1996.

C-2.3 Safety and Personnel Protection.

A Guide to the Safe Handling of Hazardous Materials Accidents, ASTM STP 825, American Society for Testing and Materials, Philadelphia, PA, 2nd edition, 1990.

Fire Protection Handbook, National Fire Protection Association, Quincy, MA, 18th edition.

Guidelines for Decontamination of Firefighters and Their Equipment Following Hazardous Materials Incidents, Canadian Association of Fire Chiefs, Ottawa (May 1987).

Guidelines for the Selection of Chemical Protective Clothing. Volume 1: Field Guide, A. D. Schwope, P. P. Costas, J. O. Jackson, D. J. Weitzman; Arthur D. Little, Inc., Cambridge, MA (March 1983).

Guidelines for the Selection of Chemical Protective Clothing. Volume 2: Technical and Reference Manual, A. D. Schwope, P. P. Costas, J. O. Jackson, D. J. Weitzman, J. O. Stull; Arthur D. Little, Inc., Cambridge, MA, 3rd edition (February 1987).

Hazardous Materials Emergencies Response and Control, John R. Cashman, Technomic Publishing Company, Lancaster, PA (June 1983).

Hazardous Materials for the First Responser, International Fire Service Training Association, Stillwater, OK (1988).

Hazardous Materials: Managing the Incident, Gregory Noll, Michael Hildebrand, and James Yvorra, Fire Service Publications, Stillwater, OK (1995).

Handling Radiation Emergencies, Purington and Patterson, National Fire Protection Association, Quincy, MA.

National Safety Council Safety Sheets, National Safety Council, Chicago, IL.

Radiological Health — Preparedness and Response in Radiation Accidents, U.S. Department of Health and Human Services, Washington, DC.

C-2.4 Planning Guides.

Federal Motor Carrier Safety Regulations Pocketbook, U.S. Department of Transportation, J. J. Keller and Associates, Inc., 1993.

Occupational Safety and Health Guidance Manual for Hazardous Waste Site Activities, NIOSH/OSHA/USCG/EPA, U.S. Department of Health and Human Services, NIOSH.

Hazardous Materials Emergency Planning Guide (March 1987), National Response Team.

Standard Operating Safety Guides, Environmental Response Branch, Office of Emergency and Remedial Response, U.S. Environmental Protection Agency.

C-3 Agencies and Associations.

Agency for Toxic Substances Disease Registry
1600 Clifton Road, NE
Centers for Disease Control
Atlanta, GA 30333
(800) 447-4784 dial 329-1175

American Conference of Governmental Industrial Hygienists
6500 Glenway Avenue — Building D-5
Cincinnati, OH 45211
(513) 661-7881

American Industrial Hygiene Association
2700 Prosperity Avenue, Suite 250

Fairfax, VA 22031
(703) 849-8888

American National Standards Institute, Inc.
11 W. 42nd Street, 13th Floor
New York, NY 10018
(212) 642-4900

American Petroleum Institute (API)
1220 L Street N.W., 9th Floor
Washington, DC 20005
(202) 682-8100

Association of American Railroads
50 F Street N.W.
Washington, DC 20001
(202) 639-2100

Chemical Manufacturers’ Association
2501 M Street N.W.
Washington, DC 20037
(202) 877-1100

CHEMTREC
Washington, DC

(800) 424-9300

The Chlorine Institute
2001 L Street N.W.
Washington, DC 20036
(202) 775-2790

Compressed Gas Association
1725 Jefferson Davis Highway
Arlington, VA 22202
(703) 412-0900

The Fertilizer Institute (TFI)
501 2nd Street N.E.
Washington, DC 20002
(202) 675-8250

International Society of Fire Service Instructors
P.O. Box 2320
Stafford, VA 22555
(800) 435-0005

National Fire Protection Association
1 Batterymarch Park, P.O. Box 9101
Quincy, MA 02269-9101
(617) 770-3000

Spill Control Association of America
Suite 1900

400 Renaissance Center
Detroit, MI 48243
(313) 567-0500

U.S. Department of Transportation
Research and Special Programs Administrator
Washington, DC 20590
(202) 366-4555

U.S. EPA Office of Research & Development
Publications — CERI
Cincinnati, OH 45268
(513) 684-7562

U.S. EPA Office of Solid Waste (WH-562)
Superfund Hotline
401 M Street S.W.
Washington, DC 20460
(800) 424-9346

U.S. Mine Safety and Health Administration
Department of Labor
4015 Wilson Boulevard, Room 600
Arlington, VA 22203
(703) 235-1452

U.S. National Oceanic and Atmospheric Administration
Hazardous Materials Response Branch N/CMS 34
7600 Sand Point Way NE
Seattle, WA 98115

C-4 Computer Data Base Systems.

Hazardous Materials Information Exchange (HMIX)
Federal Emergency Management Agency
State and Local Programs Support Directory
Technological Hazards Division
500 C Street S.W.
Washington, DC 20472

1997 Edition

This edition of NFPA 472, *Standard on Professional Competence of Responders to Hazardous Materials Incidents*, was prepared by the Technical Committee on Hazardous Materials Response Personnel and acted on by the National Fire Protection Association, Inc., at its Fall Meeting held November 18-20, 1996, in Nashville, TN. It was issued by the Standards Council on January 17, 1997, with an effective date of February 7, 1997, and supersedes all previous editions.

Changes other than editorial are indicated by a vertical rule in the margin of the pages on which they appear. These lines are included as an aid to the user in identifying changes from the previous edition.

This edition of NFPA 472 was approved as an American National Standard on February 7, 1997.

Origin and Development of NFPA 472

At the July 1985 NFPA Standards Council meeting, approval was given to the concept of a new project on Hazardous Materials Response Personnel. The Council directed that a proposed scope and start-up roster for the new Committee be prepared, taking into account the need to expand the Committee membership beyond the fire service and the people beyond "professional qualifications."

When establishment of the Committee was formally announced, many requests for membership were received, and similar requests continued to arrive during the first year of its existence. The first meeting of the Committee took place in October 1986.

Interest in the subject of hazardous materials, especially as it relates to the emergency responder, continues at a high level. Some of this is due to an increased awareness of the magnitude of the problem; much of it can be credited to federal regulations that have an impact on all responders.

In 1990 the Committee began reviewing the document for the purpose of revising it. The Committee established a task group that conducted a task analysis relating to hazardous materials response. Based on the task group's recommendations, the Committee revised the original document. The 1992 edition changed the original format and presented the competencies in a more complete manner.

Since 1992, several task groups have created two new levels, the Hazardous Materials Branch Officer and the Safety Officer. These new levels have been incorporated into the 1997 edition. Three new specialty levels, for tank cars, cargo tanks, and intermodal tanks, are also now included in the standard. The Committee found it necessary to make changes to clarify existing requirements, especially for the Technician level.

The gratitude of the Committee is extended to all who assisted in the development of this standard, and especially to those non-Committee members who participated so fully in this process.

Technical Committee on
Hazardous Materials Response Personnel

Peter A. McMahon, *Chair*
Principal Financial Group, NY [U]
Rep. Grand Island Fire Dept.

Gerald L. Grey, *Vice Chair*
San Francisco Fire Dept., CA [U]
Rep. The Alliance for Fire & Emergency Mgmt.

Charles J. Wright, *Secretary*
Union Pacific Railroad Co., NE [SE]

Donald Beckering, Hennepin Technical College, MN [U]

Glenn P. Benarick, Fairfax County Fire & Rescue, VA [E]

Bud Berry, 3M, MN [M]
Rep. American Society of Safety Engr

Gene P. Carlson, Oklahoma State University, OK [U]
Rep. Int'l Fire Service Training Assn.

Don L. Crowson, Arlington Fire Dept., TX [U]

Thomas F. Dalton, Consulting Services Inc., NJ [U]
Rep. Spill Control Assn. of America

James L. Daneker, Los Angeles City Fire Dept., CA [C]

Jeffery C. Davis, Assn. of American Railroads, CO [RT]

Manuel A. Ehrlich, Jr., BASF Corp., NJ [M]
Rep. Chemical Mfrs. Assn.

James A. Engman, Ansul Inc., WI [M]

John M. Eversole, Chicago Fire Dept., IL [E]
Rep. Int'l Assn. of Fire Chiefs

Remmit P. R. Gaade, Toronto Fire Dept., Ontario, Canada [E]

Joseph P. Gallagher, New York City Fire Dept., NY [E]

Gerald L. Grey, San Francisco Fire Dept., CA [U]
Rep. The Alliance for Fire and Emergency Mgmt.

H. Dieter Heinz, Heinz Laboratories Int'l, CA [E]
Rep. California State Firefighters' Assn.

John T. Higgins, Dow Corning Corp., MI [U]
Rep. NFPA Industrial Fire Protection Section

Charles L. Keller, Assn. of American Railroads, DC [E]

Louis J. Klein, Volunteer Firemens Insurance Services, PA [I]

Jan D. Kuczma, U.S. Fire Administration, MD [SE]

M. Jo McMullen, Summit County Hazardous Materials Response Team, OH [SE]

Mary Beth Michos, Prince William County Dept. of Fire/Rescue, VA [E]

Gregory G. Noll, Hildebrand & Noll Assoc., Inc., PA [SE]

Irving Owens, Rhode Island State Fire Marshal, RI [E]
Rep. Fire Marshals Assn. of North America

Daniel Gary Snell, Houston Fire Dept., TX [U]

William H. Stringfield, William H. Stringfield & Assoc., Inc., FL [SE]

Bruno Mark Wilson, Salem, OR [SE]

Charlie S. Woodard, Ft. Worth Fire Dept., TX [E]

Alternates

William Lee Bullock, Fairfax County Fire and Rescue Dept., VA [E]
(Alt. to G. P. Benarick)

Michael E. Burns, Michael E. Burns & Assoc., MD [M]
(Alt. to B. Berry)

Michael L. Donahue, Hildebrand and Noll Assoc., Inc., MD [SE]
(Alt. to G. Noll)

Leslie D. English, MacMillan Bloedel Packaging Inc., AL [U]

Committee Scope: This Committee shall have primary responsibility for documents on the requirements for the professional competence, training, procedures, and equipment for emergency responders to hazardous materials incidents.

NFPA 472

Standard for

Professional Competence of Responders to

Hazardous Materials Incidents

1997 Edition

NOTICE: An asterisk (*) following the number or letter designating a paragraph indicates that explanatory material on the paragraph can be found in Appendix A.
Information on referenced publications can be found in Chapter 12 and Appendix D.

Chapter 1 Administration

1-1 General.

1-1.1

Scope. This standard identifies the levels of competence required of responders to hazardous materials incidents. It specifically covers the competencies for first responders at the awareness level, first responders at the operational level, hazardous materials technicians, incident commanders, hazardous materials branch officers, hazardous materials branch safety officers, and other specialist employees.

1-1.2* Purpose.

The purpose of this standard is to specify minimum competencies for those who will respond to hazardous materials incidents. It is not the intent of this standard to restrict any jurisdiction from exceeding these minimum requirements.

One purpose of the competencies contained herein is to reduce the numbers of accidents, injuries, and illnesses during response to hazardous materials incidents and to help prevent exposure to hazardous materials to reduce the possibility of fatalities, illness, and disabilities affecting emergency response personnel.

1-2 Definitions.

Approved.* Acceptable to the authority having jurisdiction.

Authority Having Jurisdiction.* The organization, office, or individual responsible for approving equipment, an installation, or a procedure.

CANUTEC. The Canadian Transport Emergency Center operated by Transport Canada. CANUTEC provides emergency response information and assistance on a 24-hour basis for responders to hazardous materials incidents.

Chemical. Regulated and nonregulated hazardous materials (solids, liquids, and gases, whether natural or man-made, including petroleum products) with the potential for creating harm to people, the environment, and property when released.

Chemical Protective Clothing. Items made from chemical-resistive materials, such as clothing, hood, boots, and gloves, that are designed and configured to protect the wearer's torso, head, arms, legs, hands, and feet from hazardous materials. Chemical-protective clothing (garments) can be constructed as a single- or multipiece garment. The garment can completely enclose the wearer either by itself or in combination with the wearer's respiratory protection, attached or detachable hood, gloves, and boots.

CHEMTREC. The Chemical Transportation Emergency Center, a public service of the Chemical Manufacturers Association. CHEMTREC provides emergency response information and assistance on a 24-hour basis for responders to hazardous materials incidents.

Cold Zone. The control zone of a hazardous materials incident that contains the command post and such other support functions as are deemed necessary to control the incident. This zone is also referred to as the clean zone or support zone in other documents.

Competence. Possessing knowledge, skills, and judgment needed to perform indicated objectives satisfactorily.

Confined Space. A space that by design has limited openings for entry and exit, that has unfavorable natural ventilation that could contain or produce dangerous concentrations of air contaminants, and that is not intended for continuous occupancy. Examples of confined spaces include, but are not limited to, storage tanks, compartments of ships, process vessels, pits, silos, vats, degreasers, reaction vessels, boilers, ventilation and exhaust ducts, sewers, tunnels, underground utility vaults, and pipelines.

Confinement. Those procedures taken to keep a material, once released, in a defined or local area.

Container. Any vessel or receptacle that holds material, including storage vessels, pipelines, and packaging (*see definition of "Packaging*"). Containers include the following:
(a) Nonbulk packaging, such as bags, bottles, boxes, carboys, cylinders, drums, jerricans, multicell packages, and wooden barrels

(b) Bulk packaging, such as bulk bags, bulk boxes, cargo tanks, covered hopper cars, freight containers, gondolas, pneumatic hopper trailers, portable tanks and bins, protective overpacks for radioactive materials, tank cars, ton containers, and van trailers

(c) Fixed containers, such as piping, reactors, storage bins, tanks, and storage vessels

Containment. The actions taken to keep a material in its container (e.g., stop a release of the material or reduce the amount being released).

Contaminant. A hazardous material that physically remains on or in people, animals, the environment, or equipment, thereby creating a continuing risk of direct injury or a risk of exposure.

Contamination. The process of transferring a hazardous material from its source to people, animals, the environment, and/or equipment, which may act as a carrier.

Control. The procedures, techniques, and methods used in the mitigation of a hazardous materials incident, including containment, extinguishment, and confinement.

Control Zones. The areas at hazardous materials incidents that are designated based upon the degree of hazard. Many terms are used to describe these control zones; however, for the purposes of this standard, these zones are defined as the hot, warm, and cold zones.

Coordination. The process used to get people, who might represent different agencies, to work together integrally and harmoniously in a common action or effort.

Decontamination. The physical or chemical process of reducing and preventing the spread of contaminants from persons and equipment used at a hazardous materials incident.

Decontamination Corridor. The area usually located within the warm zone where decontamination procedures take place. This area is also referred to as the decontamination area in other documents.

Degradation.

(a) A chemical action involving the molecular breakdown of a protective clothing material or equipment due to contact with a chemical.

(b) The molecular breakdown of the spilled or released material to render it less hazardous during control operations.

Demonstrate. To show by actual performance. This performance can be supplemented by simulation, explanation, illustration, or a combination of these.

Describe. To explain verbally or in writing using standard terms recognized in the hazardous materials response community.

Emergency Decontamination. The physical process of immediately reducing contamination of individuals in potentially life-threatening situations with or without the formal establishment of a decontamination corridor.

Emergency Response Plan. A plan that establishes guidelines for handling hazardous materials incidents as required by relevant legislation such as Title 29, *Code of Federal Regulations*, Part 1910.120 (q) (1).

Endangered Area. The actual or potential area of exposure from a hazardous material. This area is sometimes referred to as the engulfed area.

Exposure. The process by which people, animals, the environment, and equipment are subjected to or come in contact with a hazardous material. The magnitude of exposure is dependent primarily upon the duration of exposure and the concentration of the hazardous material. This term is also used to describe a person, animal, the environment, or a piece of equipment.

Gross Decontamination. The initial phase of the decontamination process during which the amount of surface contaminant is significantly reduced. This phase can include mechanical removal or initial rinsing.

Hazard/Hazardous. Capable of posing an unreasonable risk to health, safety, or the environment; capable of causing harm.

Hazardous Material.* A substance (solid, liquid, or gas) that when released is capable of creating harm to people, the environment, and property.

Hazardous Materials Branch. That function within an overall incident management system that deals with the mitigation of the hazardous materials portion of a hazardous materials incident. It is directed by a hazardous materials branch officer and deals principally with the technical aspects of the incident.

Hazardous Materials Branch Officer. The person responsible for the management of the hazardous materials branch.

Hazardous Materials Response Team. An organized group of trained response personnel operating under an emergency response plan and appropriate standard operating procedures who handle and control actual or potential leaks or spills of hazardous materials requiring possible close approach to the material. The team members respond to releases or potential releases of hazardous materials for the purpose of control or stabilization of the incident.

High Temperature-Protective Clothing. Protective clothing designed to protect the wearer for short-term high temperature exposures. This type of clothing is usually of limited use in dealing with chemical commodities.

Hot Zone. The control zone immediately surrounding a hazardous materials incident, which extends far enough to prevent adverse effects from hazardous materials releases to personnel outside the zone. This zone is also referred to as the exclusion zone or the restricted zone in other documents.

Identify. To select or indicate verbally or in writing using standard terms to establish the identity of; the fact of being the same as the one described.

Incident. An emergency involving the release or potential release of a hazardous material, with or without fire.

Incident Commander. The person responsible for all decisions relating to the management of the incident. The incident commander is in charge of the incident site. This is equivalent to the on-scene incident commander.

Incident Management System.* An organized system of roles, responsibilities, and standard operating procedures used to manage and direct emergency operations. Such systems are sometimes referred to as incident command systems (ICS).

Individual Area of Specialization. The qualifications or functions of a specific job(s) associated with chemicals and/or containers used within an organization.

Liquid Splash-Protective Clothing. The garment portion of a chemical-protective clothing ensemble that is designed and configured to protect the wearer against chemical liquid splashes but not against chemical vapors or gases. Liquid splash-protective clothing must meet the requirements of NFPA 1992, *Standard on Liquid Splash-Protective Suits for Hazardous Chemical Emergencies.* This type of protective clothing is a component of EPA Level B chemical protection.

Listed.* Equipment, materials, or services included in a list published by an organization that is acceptable to the authority having jurisdiction and concerned with evaluation of products or services, that maintains periodic inspection of production of listed equipment or materials or periodic evaluation of services, and whose listing states that either the equipment, material, or service meets identified standards or has been tested and found suitable for a specified purpose.

Local Emergency Response Plan. The plan promulgated by the authority having jurisdiction, such as the local emergency planning committee for the community or a facility.

Match. To provide with a counterpart.

Material Safety Data Sheet (MSDS). A form, provided by manufacturers and compounders (blenders) of chemicals, containing information about chemical composition, physical and chemical properties, health and safety hazards, emergency response, and waste disposal of the material.

Monitoring Equipment. Instruments and devices used to identify and quantify contaminants.

North American Emergency Response Guidebook (NAERG). A reference book, written in plain language, to guide emergency responders in their initial actions at the incident scene.

Objective. A goal that is achieved through the attainment of a skill, knowledge, or both, that can be observed or measured.

Organization's Area of Specialization. Any chemicals and containers used by the private sector specialist employee's employer.

Packaging. Any container that holds a material (hazardous and nonhazardous). Packaging for hazardous materials includes bulk and nonbulk packaging.

Bulk Packaging. Any packaging, including transport vehicles, having a capacity meeting one of the criteria listed below. Bulk packaging can be either placed on or in a transport vehicle or vessel or constructed as an integral part of the transport vehicle.

(a) Liquid - internal volume of more than 119 gal (450 L)

(b) Solid - capacity of more than 882 lb (400 kg)

(c) Compressed gas - water capacity of more than 1,001 lb (454 kg)

Nonbulk Packaging. Any packaging having a capacity meeting one of the following criteria:

(a) Liquid - internal volume of 119 gal (450 L) or less

(b) Solid - capacity of 882 lb (400 kg) or less

(c) Compressed gas - water capacity of 1,001 lb (454 kg) or less

Penetration. The movement of a material through a suit's closures, such as zippers, buttonholes, seams, flaps, or other design features of chemical-protective clothing, and through punctures, cuts, and tears.

Permeation. A chemical action involving the movement of a chemical, on a molecular level, through intact material.

Personal Protective Equipment. The equipment provided to shield or isolate a person from the chemical, physical, and thermal hazards that can be encountered at a hazardous materials incident. Personal protective equipment includes both personal protective clothing and respiratory protection. Adequate personal protective equipment should protect the respiratory system, skin, eyes, face, hands, feet, head, body, and hearing.

Planned Response.* The plan of action, with safety considerations, consistent with the local emergency response plan and an organization's standard operating procedures for a specific hazardous materials incident.

Protective Clothing. Equipment designed to protect the wearer from heat and/or hazardous materials contacting the skin or eyes. Protective clothing is divided into three types:

(a) Structural fire-fighting protective clothing

(b) Chemical protective clothing

1. Liquid splash-protective clothing
2. Vapor-protective clothing

(c) High temperature-protective clothing

Qualified. Having satisfactorily completed the learning objectives.

Radioactive Material. Any material that spontaneously emits ionizing radiation.

Respiratory Protection. Equipment designed to protect the wearer from the inhalation of contaminants. Respiratory protection is divided into three types:

(a) Positive pressure self-contained breathing apparatus

(b) Positive pressure airline respirators

(c) Air purifying respirators

Response. That portion of incident management in which personnel are involved in controlling a hazardous materials incident. The activities in the response portion of a hazardous materials incident include analyzing the incident, planning the response, implementing the planned response, evaluating progress, and terminating the emergency phase of the incident.

Safely. To perform the assigned tasks without injury to self or others, to the environment, or to property.

Secondary Contamination. The process by which a contaminant is carried out of the hot zone and contaminates people, animals, the environment, or equipment.

SETIQ. The Emergency Transportation System for the Chemical Industry in Mexico.

Shall. Indicates a mandatory requirement.

Should. Indicates a recommendation or that which is advised but not required.

Stabilization. The point in an incident at which the adverse behavior of the hazardous material is controlled.

State. Any outlying U.S. areas where this standard is in effect. Use of the noun "state" shall also imply "provinces and territories" in Canada.

Structural Fire-Fighting Protective Clothing. Often called turnout or bunker gear, the protective clothing normally worn by fire fighters during structural fire-fighting operations. It includes a helmet, coat, pants, boots, gloves, PASS device, and a hood to cover parts of the head not protected by the helmet and facepiece. Structural fire fighters' protective clothing provides limited protection from heat but might not provide adequate protection from the harmful gases, vapors, liquids, or dusts that are encountered during hazardous materials incidents.

Termination. That portion of incident management in which personnel are involved in documenting safety procedures, site operations, hazards faced, and lessons learned from the incident. Termination is divided into three phases: debriefing the incident, post-incident analysis, and critiquing the incident.

UN/NA Identification Number. Four-digit numbers assigned to a hazardous material. The number is used to identify and cross-reference products in the transportation mode.

Vapor-Protective Clothing. The garment portion of a chemical-protective clothing ensemble that is designed and configured to protect the wearer against chemical vapors or gases. Vapor-protective clothing must meet the requirements of NFPA 1991, *Standard on Vapor-Protective Suits for Hazardous Chemical Emergencies.* This type of protective clothing is a component of EPA Level A chemical protection.

Warm Zone. The control zone at a hazardous materials incident site where personnel and equipment decontamination and hot zone support takes place. It includes control points for the decontamination corridor, thus helping to reduce the spread of contamination. This zone is also referred to as the decontamination zone or limited access zone in other documents.

Chapter 2 Competencies for the First Responder at the Awareness Level

2-1 General.

2-1.1 Introduction.

First responders at the awareness level shall be trained to meet all competencies of this chapter. They also shall receive any additional training to meet applicable United States Department of Transportation (DOT), United States Environmental Protection Agency (EPA), Occupational Safety and Health Administration (OSHA), and other appropriate state, local, or provincial occupational health and safety regulatory requirements.

2-1.2 Definition.

First responders at the awareness level are those persons who, in the course of their normal duties, could be the first on the scene of an emergency involving hazardous materials. First responders at the awareness level are expected to recognize the presence of hazardous materials, protect themselves, call for trained personnel, and secure the area.

2-1.3 Goal.

The goal of the competencies at the awareness level shall be to provide first responders with the knowledge and skills to perform the following tasks safely. Therefore, when first on the scene of an emergency involving hazardous materials, the first responder at the awareness level shall be able to:

(a) Analyze the incident to determine both the hazardous materials present and the basic hazard and response information for each hazardous material by completing the following tasks:

1. Detect the presence of hazardous materials

2. Survey a hazardous materials incident from a safe location to identify the name, UN/NA identification number, or type placard applied for any hazardous materials involved

3. Collect hazard information from the current edition of the *North American Emergency Response Guidebook*

(b) Implement actions consistent with the local emergency response plan, the organization's standard operating procedures, and the current edition of the *North American Emergency Response Guidebook* by completing the following tasks:

1. Initiate protective actions
2. Initiate the notification process

2-2 Competencies - Analyzing the Incident.

2-2.1 Detecting the Presence of Hazardous Materials.

Given various facility or transportation situations, or both, with and without hazardous materials present, the first responder at the awareness level shall identify those situations where hazardous materials are present. The first responder at the awareness level shall be able to:

2-2.1.1* Identify the definition of hazardous materials (or dangerous goods, in Canada).

2-2.1.2* Identify the DOT hazard classes and divisions of hazardous materials and identify common examples of materials in each hazard class or division.

2-2.1.3* Identify the primary hazards associated with each of the DOT hazard classes and divisions of hazardous materials by hazard class or division.

2-2.1.4 Identify the difference between hazardous materials incidents and other emergencies.

2-2.1.5 Identify typical occupancies and locations in the community where hazardous materials are manufactured, transported, stored, used, or disposed of.

2-2.1.6 Identify typical container shapes that can indicate hazardous materials.

2-2.1.7 Identify facility and transportation markings and colors that indicate hazardous materials, including the following:

(a) UN/NA identification numbers

(b) NFPA 704 markings

(c) Military hazardous materials markings

(d) Special hazard communication markings

(e) Pipeline markings

(f) Container markings

2-2.1.8 Given an NFPA 704 marking, describe the significance of the colors, numbers, and special symbols.

2-2.1.9 Identify U.S. and Canadian placards and labels that indicate hazardous materials.

2-2.1.10 Identify the basic information on material safety data sheets (MSDS) and shipping papers that indicates hazardous materials.

2-2.1.10.1 Identify where to find material safety data sheets (MSDS).

2-2.1.10.2 Identify entries on a material safety data sheet that indicate the presence of hazardous materials.

2-2.1.10.3 Identify the entries on shipping papers that indicate the presence of hazardous materials.

2-2.1.10.4 Match the name of the shipping papers found in transportation (air, highway, rail, and water) with the mode of transportation.

2-2.1.10.5 Identify the person responsible for having the shipping papers in each mode of transportation.

2-2.1.10.6 Identify where the shipping papers are found in each mode of transportation.

2-2.1.10.7 Identify where the papers can be found in an emergency in each mode of transportation.

2-2.1.11* Identify examples of clues (other than occupancy/location, container shape, markings/color, placards/labels, MSDS, and shipping papers) that use the senses of sight, sound, and odor to indicate hazardous materials.

2-2.1.12 Describe the limitations of using the senses in determining the presence or absence of hazardous materials.

2-2.2 Surveying the Hazardous Materials Incident from a Safe Location.

Given examples of facility and transportation situations involving hazardous materials, the first responder at the awareness level shall identify the hazardous material(s) in each situation by name, UN/NA identification number, or type placard applied. The first responder at the awareness level shall be able to:

2-2.2.1 Identify difficulties encountered in determining the specific names of hazardous materials in both facilities and transportation.

2-2.2.2 Identify sources for obtaining the names of, UN/NA identification numbers for, or types of placard associated with hazardous materials in transportation.

2-2.2.3 Identify sources for obtaining the names of hazardous materials in a facility.

2-2.3* Collecting Hazard Information.

Given the identity of various hazardous materials (name, UN/NA identification number, or type placard), the first responder at the awareness level shall identify the fire, explosion, and health hazard information for each material by using the current edition of the *North American Emergency Response Guidebook*. The first responder at the awareness level shall be able to:

2-2.3.1* Identify the three methods for determining the appropriate guide page for a hazardous material.

2-2.3.2 Identify the two general types of hazards found on each guide page.

2-3 Competencies - Planning the Response.

(No competencies currently required at this level.)

2-4 Competencies - Implementing the Planned Response.

2-4.1* Initiating Protective Actions.

Given examples of facility and transportation hazardous materials incidents, the local emergency response plan, the organization's standard operating procedures, and the current edition of the *North American Emergency Response Guidebook*, first responders at the awareness level shall be able to identify the actions to be taken to protect themselves and others and to control access to the scene. The first responder at the awareness level shall be able to:

2-4.1.1 Identify the location of both the local emergency response plan and the organization's standard operating procedures.

2-4.1.2 Identify the role of the first responder at the awareness level during a hazardous materials incident.

2-4.1.3 Identify the basic precautions to be taken to protect themselves and others in a hazardous materials incident.

2-4.1.3.1 Identify the precautions necessary when providing emergency medical care to victims of hazardous materials incidents.

2-4.1.3.2 Identify typical ignition sources found at the scenes of hazardous materials incidents.

2-4.1.3.3* Identify the ways hazardous materials are harmful to people, the environment, and property at hazardous materials incidents.

2-4.1.3.4* Identify the general routes of entry for human exposure to hazardous materials.

2-4.1.4* Given the identity of various hazardous materials (name, UN/NA identification number, or type placard), identify the following response information:

(a) Emergency action (fire, spill, or leak and first aid)

(b) Personal protective equipment necessary

(c) Initial isolation and protective action distances

2-4.1.4.1 Given the name of a hazardous material, identify the recommended personal protective equipment from the following list:

(a) Street clothing and work uniforms

(b) Structural fire-fighting protective clothing

(c) Positive pressure self-contained breathing apparatus

(d) Chemical-protective clothing and equipment

2-4.1.4.2 Identify the definitions for each of the following protective actions:

(a) Isolation of the hazard area and denial of entry

(b) Evacuation

(c)* Sheltering in-place protection

2-4.1.4.3 Identify the shapes of recommended initial isolation and protective action zones.

2-4.1.4.4 Describe the difference between small and large spills as found in the table of Initial Isolation and Protective Action Distances.

2-4.1.4.5 Identifying the circumstances under which the following distances are used at a hazardous materials incident:

(a) Table of initial isolation and protective action distances

(b) Isolation distances in the numbered guides

2-4.1.4.6 Describe the difference between the isolation distances in the orange-bordered guide pages and the protective action distances in the green-bordered pages in the document.

2-4.1.5 Identify the techniques used to isolate the hazard area and deny entry to unauthorized persons at hazardous materials incidents.

2-4.2 Initiating the Notification Process.

Given either a facility or transportation scenario involving hazardous materials, the first responder at the awareness level shall identify the appropriate initial notifications to be made and how to make them, consistent with the local emergency response plan or the organization's standard operating procedures.

2-5 Competencies - Evaluating Progress.

(No competencies currently required at this level.)

2-6 Competencies - Terminating the Incident.

(No competencies currently required at this level.)

Chapter 3 Competencies for the First Responder at the Operational Level

3-1 General.

3-1.1 Introduction.

First responders at the operational level shall be trained to meet all competencies at the first responder awareness levels and the competencies of this chapter. First responders at the operational level also shall receive any additional training to meet applicable United States Department of Transportation (DOT), United States Environmental Protection Agency (EPA), Occupational Safety and Health Administration (OSHA), and other appropriate state, local, or provincial occupational health and safety regulatory requirements.

3-1.2 Definition.

First responders at the operational level are those persons who respond to releases or potential releases of hazardous materials as part of the initial response to the incident for the purpose of protecting nearby persons, the environment, or property from the effects of the release. First responders at the operational level are expected to respond in a defensive fashion to control the release from a safe distance and keep it from spreading.

3-1.3 Goal.

The goal of the competencies at the operational level shall be to provide first responders with the knowledge and skills to perform the following tasks safely. Therefore, in addition to being competent at the awareness level, the first responder at the operational level shall be able to:

(a) Analyze a hazardous materials incident to determine the magnitude of the problem in terms of outcomes by completing the following tasks:

1. Survey the hazardous materials incident to identify the containers and materials involved, determine whether hazardous materials have been released, and evaluate the surrounding conditions

2. Collect hazard and response information from material safety data sheets (MSDS), CHEMTREC/CANUTEC/SETIQ, and shipper/manufacturer contacts

3. Predict the likely behavior of a material as well as its container

4. Estimate the potential harm at a hazardous materials incident

(b) Plan an initial response within the capabilities and competencies of available personnel, personal protective equipment, and control equipment by completing the following tasks:

1. Describe the response objectives for hazardous materials incidents

2. Describe the defensive options available for a given response objective

3. Determine whether the personal protective equipment provided is appropriate for implementing each defensive option

4. Identify the emergency decontamination procedures

(c) Implement the planned response to favorably change the outcomes consistent with the local emergency response plan and the organization's standard operating procedures by completing the following tasks:

1. Establish and enforce scene control procedures including control zones, emergency decontamination, and communications

2. Initiate an incident management system (IMS) for hazardous materials incidents

3. Don, work in, and doff personal protective equipment provided by the authority having jurisdiction

4. Perform defensive control functions identified in the plan of action

(d) Evaluate the progress of the actions taken to ensure that the response objectives are being met safely, effectively, and efficiently by completing the following tasks:

1. Evaluate the status of the defensive actions taken in accomplishing the response objectives

2. Communicate the status of the planned response

3-2 Competencies - Analyzing the Incident.

3-2.1* Surveying the Hazardous Materials Incident.

Given examples of both facility and transportation scenarios involving hazardous materials, the first responder at the operational level shall survey the incident to identify the containers and materials involved, determine whether hazardous materials have been released, and evaluate the surrounding conditions. The first responder at the operational level shall be able to:

3-2.1.1* Given three (3) examples each of liquid, gas, and solid hazardous materials, identify the general shapes of containers in which the hazardous materials are typically found.

3-2.1.1.1 Given examples of the following tank cars, identify each tank car by type:

(a) Nonpressure tank cars with and without expansion domes

(b) Pressure tank cars

(c) Cryogenic liquid tank cars

3-2.1.1.2 Given examples of the following intermodal tank containers, identify each intermodal tank container by type:

(a) Nonpressure intermodal tank containers

(b) Pressure intermodal tank containers

3-2.1.1.3 Given examples of the following cargo tanks, identify each cargo tank by type:

(a) MC-306/DOT 406 cargo tanks

(b) MC-307/DOT-407 cargo tanks

(c) MC-312/DOT-412 cargo tanks

(d) MC-331 cargo tanks

(e) MC-338 cargo tanks

(f) Dry bulk cargo tanks

3-2.1.1.4 Given examples of the following facility tanks, identify each fixed facility tank by type:

(a) Nonpressure facility tanks

(b) Pressure facility tanks

(c) Cryogenic liquid tanks

3-2.1.1.5 Given examples of the following nonbulk packages, identify each package by type:

(a) Bags

(b) Carboys

(c) Cylinders

(d) Drums

3-2.1.2 Given examples of facility and transportation containers, identify the markings that differentiate one container from another.

3-2.1.2.1 Given examples of the following marked transport vehicles and their corresponding shipping papers, identify the vehicle or tank identification marking:

(a) Rail transport vehicles, including tank cars

(b) Intermodal equipment including tank containers

(c) Highway transport vehicles, including cargo tanks

3-2.1.2.2 Given examples of facility containers, identify the markings indicating container size, product contained, and/or site identification numbers.

3-2.1.3 Given examples of facility and transportation situations involving hazardous materials, identify the name(s) of the hazardous material(s) in each situation.

3-2.1.3.1 Identify the following information on a pipeline marker:

(a) Product

(b) Owner

(c) Emergency telephone number

3-2.1.3.2 Given a pesticide label, identify each of the following pieces of information; then match the piece of information to its significance in surveying the hazardous materials incident:

(a) Name of pesticide

(b) Signal word

(c) Pest control product (PCP) number (in Canada)

(d) Precautionary statement

(e) Hazard statement

(f) Active ingredient

3-2.1.4* Identify and list the surrounding conditions that should be noted by the first responders when surveying hazardous materials incidents.

3-2.1.5 Give examples of ways to verify information obtained from the survey of a hazardous materials incident.

3-2.2 Collecting Hazard and Response Information.

Given known hazardous materials, the first responder at the operational level shall collect hazard and response information using material safety data sheets (MSDS), CHEMTREC/CANUTEC/SETIQ, and contacts with the shipper/manufacturer. The first responder at the operational level shall be able to:

3-2.2.1 Match the definitions associated with the DOT hazard classes and divisions of hazardous materials, including refrigerated liquefied gases and cryogenic liquids, with the class or division.

3-2.2.2 Identify two ways to obtain a material safety data sheet (MSDS) in an emergency.

3-2.2.3 Using a material safety data sheet (MSDS) for a specified material, identify the following hazard and response information:

(a) Physical and chemical characteristics

(b) Physical hazards of the material

(c) Health hazards of the material

(d) Signs and symptoms of exposure

(e) Routes of entry

(f) Permissible exposure limits

(g) Responsible party contact

(h) Precautions for safe handling (including hygiene practices, protective measures, procedures for cleanup of spills or leaks)

(i) Applicable control measures including personal protective equipment

(j) Emergency and first aid procedures

3-2.2.4 Identify the following:

(a) Type of assistance provided by CHEMTREC/CANUTEC/SETIQ

(b) Procedure for contacting CHEMTREC/CANUTEC/SETIQ

(c) Information to be furnished to CHEMTREC/CANUTEC/SETIQ

3-2.2.5 Identify two methods of contacting the manufacturer or shipper to obtain hazard and response information.

3-2.3* Predicting the Behavior of a Material and its Container.

Given an incident involving a single hazardous material, the first responder at the operational level shall predict the likely behavior of the material and its container. The first responder at the operational level shall be able to:

3-2.3.1 Given two examples of scenarios involving known hazardous materials, interpret the hazard and response information obtained from the current edition of the *North American Emergency Response Guidebook*, material safety data sheets (MSDS), CHEMTREC/CANUTEC/SETIQ, and shipper/manufacturer contacts.

3-2.3.1.1 Match the following chemical and physical properties with their significance and impact on the behavior of the container and/or its contents:

(a) Boiling point

(b) Chemical reactivity

(c) Corrosivity (pH)

(d) Flammable (explosive) range (LEL & UEL)

(e) Flash point

(f) Ignition (autoignition) temperature

(g) Physical state (solid, liquid, gas)

(h) Specific gravity

(i) Toxic products of combustion

(j) Vapor density

(k) Vapor pressure

(l) Water solubility

3-2.3.1.2 Identify the differences among the following terms:

(a) Exposure and hazard

(b) Exposure and contamination

(c) Contamination and secondary contamination

3-2.3.2* Identify three types of stress that could cause a container system to release its contents.

3-2.3.3* Identify five ways in which containers can breach.

3-2.3.4* Identify four ways in which containers can release their contents.

3-2.3.5* Identify at least four dispersion patterns that can be created upon release of a hazardous material.

3-2.3.6* Identify the three general time frames for predicting the length of time that exposures can be in contact with hazardous materials in an endangered area.

3-2.3.7* Identify the health and physical hazards that could cause harm.

3-2.3.8* Identify the health hazards associated with the following terms:

(a) Asphyxiant

(b)* Chronic health hazard

(c) Convulsant

(d) Irritant/corrosive

(e) Sensitizer/allergen

3-2.4* Estimating the Potential Harm.

The first responder at the operational level shall estimate the potential harm within the endangered area at a hazardous materials incident. The first responder at the operational level shall be able to:

3-2.4.1* Identify a resource for determining the size of an endangered area of a hazardous materials incident.

3-2.4.2 Given the dimensions of the endangered area and the surrounding conditions at a hazardous materials incident, estimate the number and type of exposures within that endangered area.

3-2.4.3 Identify resources available for determining the concentrations of a released hazardous material within an endangered area.

3-2.4.4* Given the concentrations of the released material, identify the factors for determining the extent of physical, health, and safety hazards within the endangered area of a hazardous materials incident.

3-3 Competencies - Planning the Response.

3-3.1 Describing Response Objectives for Hazardous Materials Incidents.

Given at least two scenarios involving hazardous materials incidents (one facility and one transportation), the first responder at the operational level shall describe the first responder's response objectives for each problem. The first responder at the operational level shall be able to:

3-3.1.1 Given an analysis of a hazardous materials problem and the exposures already lost, identify the steps for determining the number of exposures that could be saved by the first responder with the resources provided by the authority having jurisdiction and operating in a defensive fashion.

3-3.1.2 Given an analysis of a hazardous materials incident, describe the steps for determining defensive response objectives.

3-3.2 Identifying Defensive Options.

Given simulated facility and transportation hazardous materials problems, the first responder at the operational level shall identify the defensive options for each response objective. The first responder at the operational level shall be able to:

3-3.2.1 Identify the defensive options to accomplish a given response objective.

3-3.2.2 Identify the purpose for, and the procedures, equipment, and safety precautions used with, each of the following control techniques:

(a) Absorption

(b) Dike, dam, diversion, retention

(c) Dilution

(d) Remote valve shutoff

(e) Vapor dispersion

(f) Vapor suppression

3-3.3 Determining Appropriateness of Personal Protective Equipment.

Given the name of the hazardous material involved and the anticipated type of exposure, the first responder at the operational level shall determine whether available personal protective equipment is appropriate for implementing a defensive option. The first responder at the operational level shall be able to:

3-3.3.1* Identify the appropriate respiratory protection required for a given defensive option.

3-3.3.1.1 Identify the three types of respiratory protection and the advantages and limitations presented by the use of each at hazardous materials incidents.

3-3.3.1.2 Identify the required physical capabilities and limitations of personnel working in positive pressure self-contained breathing apparatus.

3-3.3.2 Identify the appropriate personal protective clothing required for a given defensive option.

3-3.3.2.1 Identify skin contact hazards encountered at hazardous materials incidents.

3-3.3.2.2 Identify the purpose, advantages, and limitations of the following levels of protective clothing at hazardous materials incidents:

(a) Structural fire-fighting protective clothing

(b) High temperature-protective clothing

(c) Chemical-protective clothing

1. Liquid splash-protective clothing

2. Vapor-protective clothing

3-3.4* Identifying Emergency Decontamination Procedures.

The first responder at the operational level shall identify emergency decontamination procedures. The first responder at the operational level shall be able to:

3-3.4.1 Identify ways that personnel, personal protective equipment, apparatus, and tools and equipment become contaminated.

3-3.4.2 Describe how the potential for secondary contamination determines the need for emergency decontamination procedures.

3-3.4.3 Identify the purpose of emergency decontamination procedures at hazardous materials incidents.

3-3.4.4 Identify the advantages and limitations of emergency decontamination procedures.

3-4 Competencies - Implementing the Planned Response.

3-4.1 Establishing and Enforcing Scene Control Procedures.

Given scenarios for facility and/or transportation hazardous materials incidents, the first responder at the operational level shall identify how to establish and enforce scene control including control zones, emergency decontamination, and communications. The first responder at the operational level shall be able to:

3-4.1.1 Identify the procedures for establishing scene control through control zones.

3-4.1.2 Identify the criteria for determining the locations of the control zones at hazardous materials incidents.

3-4.1.3 Identify the basic techniques for the following protective actions at hazardous materials incidents:

(a) Evacuation

(b) Sheltering in-place protection

3-4.1.4 Identify the considerations associated with locating emergency decontamination areas.

3-4.1.5* Demonstrate the ability to perform emergency decontamination.

3-4.1.6* Identify the items to be considered in a safety briefing prior to allowing personnel to work on a hazardous materials incident.

3-4.2* Initiating the Incident Management System (IMS).

Given simulated facility and/or transportation hazardous materials incidents, the first responder at the operational level shall initiate the incident management system (IMS) specified in the local emergency response plan and the organization's standard operating procedures. The first responder at the operational level shall be able to:

3-4.2.1 Identify the role of the first responder at the operational level during hazardous materials incidents as specified in the local emergency response plan and the organization's standard operating procedures.

3-4.2.2 Identify the levels of hazardous materials incidents as defined in the local emergency response plan.

3-4.2.3 Identify the purpose, need, benefits, and elements of an incident management system (IMS) at hazardous materials incidents.

3-4.2.4 Identify the considerations for determining the location of the command post for a hazardous materials incident.

3-4.2.5 Identify the procedures for requesting additional resources at a hazardous materials incident.

3-4.2.6* Identify the authority and responsibilities of the safety officer.

3-4.3 Using Personal Protective Equipment.

The first responder at the operational level shall demonstrate the ability to don, work in, and doff the personal protective equipment provided by the authority having jurisdiction. The first responder at the operational level shall be able to:

3-4.3.1 Identify the importance of the buddy system in implementing the planned defensive options.

3-4.3.2 Identify the importance of the backup personnel in implementing the planned defensive options.

3-4.3.3 Identify the safety precautions to be observed when approaching and working at hazardous materials incidents.

3-4.3.4 Identify the symptoms of heat and cold stress.

3-4.3.5 Identify the physical capabilities required for, and the limitations of, personnel working in the personal protective equipment as provided by the authority having jurisdiction.

3-4.3.6 Match the function of the operational components of the positive pressure self-contained breathing apparatus provided to the hazardous materials responder with the name of the component.

3-4.3.7 Identify the procedures for cleaning, disinfecting, and inspecting respiratory protective equipment.

3-4.3.8 Identify the procedures for donning, working in, and doffing positive pressure self-contained breathing apparatus.

3-4.3.9 Demonstrate donning, working in, and doffing positive pressure self-contained breathing apparatus.

3-4.4 Performing Defensive Control Actions.

Given a plan of action for a hazardous materials incident within their capabilities, the first responder at the operational level shall demonstrate defensive control actions set out in the plan. The first responder at the operational level shall be able to:

3-4.4.1 Using the type of fire-fighting foam or vapor suppressing agent and foam equipment furnished by the authority having jurisdiction, demonstrate the proper application of the fire-fighting foam(s) or vapor suppressing agent(s) on a spill or fire involving hazardous materials.

3-4.4.2 Identify the characteristics and applicability of the following foams:

(a) Protein

(b) Fluoroprotein

(c) Special purpose

1. Polar solvent alcohol-resistant concentrates
2. Hazardous materials concentrates

(d) Aqueous film-forming foam (AFFF)

(e) High expansion

3-4.4.3 Given the appropriate tools and equipment, demonstrate how to perform the following defensive control activities:

(a) Absorption

(b) Damming

(c) Diking

(d) Dilution

(e) Diversion

(f) Retention

(g) Vapor dispersion

(h) Vapor suppression

3-4.4.4 Identify the location and describe the use of the mechanical, hydraulic, and air emergency remote shutoff devices as found on cargo tanks.

3-4.4.5 Describe the objectives and dangers of search and rescue missions at hazardous materials incidents.

3-5 Competencies - Evaluating Progress.

3-5.1 Evaluating the Status of Defensive Actions.

Given simulated facility and/or transportation hazardous materials incidents, the first responder at the operational level shall evaluate the status of the defensive actions taken in accomplishing the response objectives. The first responder at the operational level shall be able to:

3-5.1.1 Identify the considerations for evaluating whether defensive options are effective in accomplishing the objectives.

3-5.1.2 Describe the circumstances under which it would be prudent to withdraw from a hazardous materials incident.

3-5.2 Communicating the Status of the Planned Response.

The first responder at the operational level shall communicate the status of the planned response to the incident commander and other response personnel. The first responder at the operational level shall be able to:

3-5.2.1 Identify the methods for communicating the status of the planned response to the incident commander through the normal chain of command.

3-5.2.2 Identify the methods for immediate notification of the incident commander and other response personnel about critical emergency conditions at the incident.

3-6 Competencies - Terminating the Incident.

(No competencies currently required at this level.)

Chapter 4 Competencies for the Hazardous Materials Technician

4-1 General.

4-1.1 Introduction.

Hazardous materials technicians shall be trained to meet all competencies at the first responder awareness and operational levels and the competencies of this chapter. Hazardous materials technicians also shall receive any additional training to meet applicable United States Department of Transportation (DOT), United States Environmental Protection Agency (EPA), Occupational Safety and Health Administration (OSHA), and other appropriate state, local, or provincial occupational health and safety regulatory requirements.

4-1.2 Definition.

Hazardous materials technicians are those persons who respond to releases or potential releases of hazardous materials for the purpose of controlling the release. Hazardous materials technicians are expected to use specialized chemical protective clothing and specialized control equipment.

4-1.3* Goal.

The goal of this chapter shall be to provide the hazardous materials technician with the knowledge and skills to perform the following tasks safely. Therefore, in addition to being competent at both the first responder awareness and operational levels, the hazardous materials technician shall be able to:

(a) Analyze a hazardous materials incident to determine the magnitude of the problem in terms of outcomes by completing the following tasks:

1. Survey the hazardous materials incident to identify special containers involved, to identify or classify unknown materials, and to verify the presence and concentrations of hazardous materials through the use of monitoring equipment

2. Collect and interpret hazard and response information from printed resources, technical resources, computer data bases, and monitoring equipment

3. Determine the extent of damage to containers

4. Predict the likely behavior of released materials and their containers when multiple materials are involved

5. Estimate the size of an endangered area using computer modeling, monitoring equipment, or specialists in this field

(b) Plan a response within the capabilities of available personnel, personal protective equipment, and control equipment by completing the following tasks:

1. Identify the response objectives for hazardous materials incidents

2. Identify the potential action options available by response objective

3. Select the personal protective equipment required for a given action option

4. Select the appropriate decontamination procedures

5. Develop a plan of action, including safety considerations, consistent with the local emergency response plan and the organization's standard operating procedures, and within the capability of the available personnel, personal protective equipment, and control equipment

(c) Implement the planned response to favorably change the outcomes consistent with the organization's standard operating procedures and safety considerations by completing the following tasks:

1. Perform the duties of an assigned hazardous materials branch position within the local incident management system (IMS)

2. Don, work in, and doff appropriate personal protective clothing, including, but not limited to, both liquid splash- and vapor-protective clothing with appropriate respiratory protection

3. Perform the control functions identified in the plan of action

(d) Evaluate the progress of the planned response by evaluating the effectiveness of the control functions

(e) Terminate the incident by completing the following tasks:

1. Assist in the incident debriefing

2. Assist in the incident critique

3. Provide reports and documentation of the incident

4-2 Competencies - Analyzing the Incident.

4-2.1 Surveying the Hazardous Materials Incident.

The hazardous materials technician shall identify special containers involved and, given the appropriate equipment, identify or classify unknown materials, verify the identity of the hazardous materials, and determine the concentration of hazardous materials. The hazardous materials technician shall be able to:

4-2.1.1 Given examples of various specialized containers, identify each container by name and identify the material, and its hazard class, that is typically found in the container.

4-2.1.1.1 Given examples of the following railroad cars, identify each car by type and identify at least one material, and its hazard class, that is typically found in each car:

(a) Cryogenic liquid tank cars

(b) High-pressure tube cars

(c) Nonpressure tank cars

(d) Pneumatically unloaded hopper car

(e) Pressure tank cars

4-2.1.1.2 Given examples of the following intermodal tanks, identify each intermodal tank by type and identify at least one material, and its hazard class, that is typically found in each tank:

(a) Nonpressure intermodal tanks:

1. IM-101 (IMO Type 1 internationally) portable tank

2. IM-102 (IMO Type 2 internationally) portable tank

(b) Pressure intermodal tanks (DOT 51) (IMO Type 5 internationally)

(c) Specialized intermodal tanks:

1. Cryogenic intermodal tanks (IMO Type 7 internationally)

2. Tube modules

4-2.1.1.3 Given examples of the following cargo tanks, identify at least one material, and its hazard class, that is typically found in each tank:

(a) Dry bulk cargo tanks

(b) MC306/DOT-406 cargo tanks

(c) MC307/DOT-407 cargo tanks

(d) MC312/DOT-412 cargo tanks

(e) MC331 cargo tanks

(f) MC-338 cargo tanks

4-2.1.1.4 Given examples of the following facility tanks, identify at least one material, and its hazard class, that is typically found in each tank:

(a) Nonpressure tank

(b) Pressure tank

4-2.1.1.5 Given examples of the following nonbulk containers, identify at least one material, and its hazard class, that is typically found in each container:

(a) Bags

(b) Carboys

(c) Cylinders

(d) Drums

4-2.1.1.6 Given examples of the following radioactive materials packages, identify each package by type and identify at least one typical material found in each package:

(a) Type A

(b) Type B

4-2.1.2 Given three examples of facility and transportation containers, identify the approximate capacity of each container.

4-2.1.2.1 Using the markings on the container, identify the capacity (by weight and/or volume) of the following examples of transportation vehicles:

(a) Cargo tanks

(b) Tank cars

(c) Tank containers

4-2.1.2.2 Using the markings on the container and other available resources, identify the capacity (by weight and/or volume) of each of the following facility containers:

(a) Nonpressure tank

(b) Pressure tank

(c) Cryogenic liquid tank

4-2.1.3* Given at least three unknown materials, one of which is a solid, one a liquid, and one a gas, identify or classify by hazard each unknown material.

4-2.1.3.1 Identify the steps in an analysis process for identifying unknown solid and liquid materials.

4-2.1.3.2 Identify the steps in an analysis process for identifying an unknown atmosphere.

4-2.1.3.3 Identify the type(s) of monitoring equipment, test strips, and reagents used to determine the following hazards:

(a) Corrosivity (pH)

(b) Flammability

(c) Oxidation potential

(d) Oxygen deficiency

(e) Radioactivity

(f) Toxic levels

4-2.1.3.4* Identify the capabilities and limiting factors associated with the selection and use of the following monitoring equipment, test strips, and reagents:

(a) Carbon monoxide meter

(b) Colorimetric tubes

(c) Combustible gas indicator

(d) Oxygen meter

(e) Passive dosimeter

(f) Photoionization detectors

(g) pH indicators and/or pH meters

(h) Radiation detection instruments

(i) Reagents

(j) Test strips

4-2.1.3.5* Given three hazardous materials, one of which is a solid, one a liquid, and one a gas, and the following monitoring equipment, test strips, and reagents, select the appropriate equipment and demonstrate the proper techniques to identify and quantify the materials:

(a) Carbon monoxide meter

(b) Colorimetric tubes

(c) Combustible gas indicator

(d) Oxygen meter

(e) pH indicators and/or pH meters

(f) Radiation detection instruments

(g) Reagents

(h) Test strips

4-2.1.3.6 Demonstrate the field maintenance and testing procedures for the monitoring equipment, test strips, and reagents provided by the authority having jurisdiction.

4-2.1.4 Given a label for a radioactive material, identify vertical bars, contents, activity, and transport index, then describe the labeled item and its significance in surveying a radioactive materials incident.

4-2.2 Collecting and Interpreting Hazard and Response Information.

Given access to printed resources, technical resources, computer data bases, and monitoring equipment, the hazardous materials technician shall collect and interpret hazard and response information not available from the current edition of the *North American Emergency Response Guidebook* or a material safety data sheet (MSDS). The hazardous materials technician shall be able to:

4-2.2.1* Identify and interpret the types of hazard and response information available from each of the following resources and explain the advantages and disadvantages of each resource:

(a) Hazardous materials data bases

(b) Maps and diagrams

(c) Monitoring equipment

(d) Reference manuals

(e) Technical information centers (i.e., CHEMTREC/CANUTEC/SETIQ)

(f) Technical information specialists

4-2.2.2 Describe the following terms and explain their significance in the risk assessment process:

(a) Acid, caustic

(b) Air reactivity

(c) Boiling point

(d) Catalyst

(e) Chemical interactions

(f) Chemical reactivity

(g) Compound, mixture

(h) Concentration

(i) Corrosivity (pH)

(j) Critical temperatures and pressure

(k) Expansion ratio

(l) Flammable (explosive) range (LEL & UEL)

(m) Fire point

(n) Flash point

(o) Halogenated hydrocarbon

(p) Ignition (autoignition) temperature

(q) Inhibitor

(r) Instability

(s) Ionic & covalent compounds

(t) Maximum safe storage temperature (MSST)

(u) Melting point/freezing point

(v) Miscibility

(w) Organic and inorganic

(x) Oxidation potential

(y) pH

(z) Physical state (solid, liquid, gas)

(aa) Polymerization

(bb) Radioactivity

(cc) Saturated, unsaturated, and aromatic hydrocarbons

(dd) Self-accelerating decomposition temperature (SADT)

(ee) Solution, slurry

(ff) Specific gravity

(gg) Strength

(hh) Sublimation

(ii) Temperature of product

(jj) Toxic products of combustion

(kk) Vapor density

(ll) Vapor pressure

(mm) Viscosity

(nn) Volatility

(oo) Water reactivity

(pp) Water solubility

4-2.2.3 Describe the heat transfer processes that occur as a result of a cryogenic liquid spill.

4-2.2.4* Given five hazardous material scenarios and the appropriate reference materials, identify the signs and symptoms of exposure to each material and the target organ effects of exposure to that material.

4-2.2.5 Given the scenario of a domestic gas line break and the readings from a combustible gas indicator, determine the area of evacuation.

4-2.2.6 Identify two methods for determining the pressure in bulk packaging or facility containers.

4-2.2.7 Identify one method for determining the amount of lading remaining in damaged bulk packaging or facility containers.

4-2.3* Describing the Condition of the Container Involved in the Incident.

Given simulated facility and transportation container damage, the hazardous materials technician shall describe the damage. The hazardous materials technician shall be able to:

4-2.3.1* Given three examples of containers, DOT specification markings for nonbulk and bulk packaging, and the appropriate reference guide, identify the basic design and construction features of each container.

4-2.3.1.1 Identify the basic design and construction features, including closures, of the following bulk containers:

(a) Cargo tanks:

1. Dry bulk cargo tanks
2. MC-306/DOT-406 cargo tanks
3. MC-307/ DOT-407 cargo tanks
4. MC-312/DOT-412 cargo tanks
5. MC-331 cargo tanks
6. MC-338 cargo tanks

(b) Fixed facility tanks:

1. Nonpressure tank
2. Pressure tank

(c) Intermodal tanks:

1. Nonpressure intermodal tanks:

a. IM- 101 portable tank

b. IM-102 portable tank

2. Pressure intermodal tanks (specification 51)

3. Specialized intermodal tanks:

a. Cryogenic intermodal tanks

b. Tube modules

(d) One-ton containers

(e) Pipelines

(f) Railroad cars:

1. Cryogenic liquid tank cars
2. High-pressure tube cars
3. Nonpressure tank cars
4. Pneumatically unloaded hopper cars
5. Pressure tank cars

(g) Intermediate bulk containers (also known as tote tanks)

4-2.3.1.2 Identify the basic design and construction features including closures of the following nonbulk containers:

(a) Carboys

(b) Drums

(c) Pressurized cylinders

4-2.3.1.3 Identify the basic design and construction features of the following radioactive materials containers:

(a) Type A package

(b) Type B package

4-2.3.2 Describe how a liquid pipeline can carry different products.

4-2.3.3 Given an example of a pipeline, identify the following:

(a) Ownership of the line

(b) Procedures for checking for gas migration

(c) Procedure for shutting down the line or controlling the leak

(d) Type of product in the line

4-2.3.4* Identify the types of damage that a pressure container could incur.

4-2.3.5 Given examples of tank car damage, identify the type of damage in each example by name.

4-2.4 Predicting Likely Behavior of Materials and Their Containers When Multiple Materials are Involved.

Given examples of both facility and transportation incidents involving multiple hazardous materials, the hazardous materials technician shall predict the likely behavior of the material in each case. The hazardous materials technician shall be able to:

4-2.4.1 Identify at least three resources available that indicate the effects of mixing various hazardous materials.

4-2.4.2 Identify the impact of the following fire and safety features on the behavior of the products during an incident at a bulk storage facility and explain their significance in the risk assessment process:

(a) Fire protection systems

(b) Monitoring and detection systems

(c) Product spillage and control (impoundment and diking)

(d) Tank spacing

(e) Tank venting and flaring systems

(f) Transfer operations

4-2.5 Estimating the Likely Size of an Endangered Area.

Given various facility and transportation hazardous materials incidents, the hazardous materials technician shall estimate the likely size, shape, and concentrations associated with the release of materials involved in the incident by using computer modeling, monitoring equipment, or specialists in this field. The hazardous materials technician shall be able to:

4-2.5.1 Identify local resources for dispersion pattern prediction and modeling including computers, monitoring equipment, or specialists in the field.

4-2.5.2 Given the concentrations of the released material, identify the steps for determining the extent of the hazards (e.g., physical, safety, and health) within the endangered area of a hazardous materials incident.

4-2.5.2.1 Describe the following toxicological terms and exposure values and explain their significance in the risk assessment process:

(a) Parts per million (ppm)

(b) Parts per billion (ppb)

(c) Lethal dose (LD_{50})

(d) Lethal concentrations (LC_{50})

(e) Permissible exposure limit (PEL)

(f) Threshold limit value time-weighted average (TLV-TWA)

(g) Threshold limit value short-term exposure limit (TLV-STEL)

(h) Threshold limit value ceiling (TLV-C)

(i) Immediately dangerous to life and health value (IDLH)

4-2.5.2.2* Describe the following radiological terms and explain their significance in predicting the extent of health hazards and environmental impact in a hazardous materials incident:

(a) Types

(b) Measurement

(c) Protection

4-2.5.2.3 Identify two methods for predicting the areas of potential harm within the endangered area of a hazardous materials incident.

4-2.5.3* Identify a method for estimating the outcomes within an endangered area of a hazardous materials incident.

4-3 Competencies - Planning the Response.

4-3.1 Identifying Response Objectives.

Given simulated facility and transportation problems, the hazardous materials technician shall describe the response objectives for each problem. The hazardous materials technician shall be able to describe the steps for determining response objectives (defensive, offensive, nonintervention) given an analysis of a hazardous materials incident.

4-3.2 Identifying the Potential Action Options.

Given simulated facility and transportation hazardous materials incidents, the hazardous materials technician shall identify the possible action options (defensive, offensive, and nonintervention) by response objective for each problem. The hazardous materials technician shall be able to identify the possible action options to accomplish a given response objective.

4-3.3 Selecting Personal Protective Equipment.

Given situations with known and unknown hazardous materials, the hazardous materials technician shall determine the appropriate personal protective equipment for the action options specified in the plan of action in each situation. The hazardous materials technician shall be able to:

4-3.3.1 Identify the four levels of personal protective equipment (EPA/NIOSH or NFPA 471) and describe the equipment for each level and the condition under which each level is used.

4-3.3.2 Identify the factors to be considered in selecting the proper respiratory protection for a specified action option.

4-3.3.2.1 Describe the advantages, limitations, and proper use of the following types of respiratory protection at hazardous materials incidents:

(a) Positive pressure self-contained breathing apparatus

(b) Positive pressure air line respirators with required escape unit

(c) Air purifying respirators

4-3.3.2.2 Identify the process for selecting the proper respiratory protection at hazardous materials incidents.

4-3.3.2.3 Identify the operational components of air purifying respirators and air line respirators by name and describe their functions.

4-3.3.3 Identify the factors to be considered in selecting the proper chemical-protective clothing for a specified action option.

4-3.3.3.1 Describe the following terms and explain their impact and significance on the selection of chemical-protective clothing:

(a) Degradation

(b) Penetration

(c) Permeation

4-3.3.3.2 Identify at least three indications of material degradation of chemical-protective clothing.

4-3.3.3.3* Identify the three types of vapor-protective and splash-protective clothing and describe the advantages and disadvantages of each type.

4-3.3.3.4 Identify the relative advantages and disadvantages of the following heat exchange units used for the cooling of personnel in chemical-protective clothing:

(a) Air cooled

(b) Ice cooled

(c) Water cooled

4-3.3.3.5 Identify the process for selecting the proper protective clothing at hazardous materials incidents.

4-3.3.3.6 Given three examples of various hazardous materials, determine the appropriate protective clothing construction materials for a given action option using chemical compatibility charts.

4-3.3.3.7 Identify the physical and psychological stresses that can affect users of specialized protective clothing.

4-3.4 Developing Appropriate Decontamination Procedures.

Given a simulated hazardous materials incident, the hazardous materials technician shall select an appropriate decontamination procedure and determine the equipment required to implement that procedure. The hazardous materials technician shall be able to:

4-3.4.1 Identify the advantages and limitations and describe an example where each of the following decontamination methods would be used:

(a) Absorption

(b) Adsorption

(c) Chemical degradation

(d) Dilution

(e) Disposal

(f) Evaporation

(g) Neutralization

(h) Solidification

(i) Vacuuming

(j) Washing

4-3.4.2 Identify three sources of technical information for selecting appropriate decontamination procedures and identify how to contact those sources in an emergency.

4-3.5 Developing a Plan of Action.

Given simulated hazardous materials incidents in facility and transportation settings, the hazardous materials technician shall develop a plan of action, including safety considerations. The plan shall be consistent with the local emergency response plan and the organization's standard operating procedures and be within the capability of available personnel, personal protective equipment, and control equipment for that incident. The hazardous materials technician shall be able to:

4-3.5.1 Describe the purpose of, procedures for, equipment required, and safety precautions used with the following techniques for hazardous materials control:

(a) Adsorption

(b) Neutralization

(c) Overpacking

(d) Patching

(e) Plugging

4-3.5.2 Given MC-306/DOT-406, MC-307/DOT-407, MC-312/DOT-412, MC-331, and MC-338 cargo tanks, identify the common methods for product transfer from each type of cargo tank.

4-3.5.3 Given a simulated hazardous materials incident, develop the safety considerations that must be included in the plan of action.

4-3.5.3.1 List and describe the safety considerations to be included.

4-3.5.3.2 Identify the points that should be made in a safety briefing prior to working at the scene.

4-3.5.4* Identify the atmospheric and physical safety hazards associated with hazardous materials incidents involving confined spaces.

4-3.5.5 Identify the pre-entry activities to be performed.

4-4 Competencies - Implementing the Planned Response.

4-4.1 Performing Incident Management Duties.

Given the local emergency response plan or organization's standard operating procedures and a simulated hazardous materials incident, the hazardous materials technician shall demonstrate the duties of an assigned hazardous materials branch position within the local incident management system (IMS). The hazardous materials technician shall be able to:

4-4.1.1 Identify the role of the hazardous materials technician during an incident involving hazardous materials.

4-4.1.2 Identify the duties and responsibilities of the following hazardous materials branch functions within the incident management system:

(a) Backup

(b) Decontamination

(c) Entry

(d) Hazardous Materials Branch Management

(e) Hazardous Materials Branch Safety

(f) Information/research

(g) Reconnaissance

(h) Resources

4-4.1.3 Demonstrate setup of the decontamination corridor as specified in the planned response.

4-4.1.4 Demonstrate the decontamination process specified in the planned response.

4-4.2 Using Protective Clothing and Respiratory Protection.

The hazardous materials technician shall demonstrate the ability to don, work in, and doff both liquid splash- and vapor-protective chemical-protective clothing and any other specialized personal protective equipment provided by the authority having jurisdiction, including the appropriate respiratory protection. The hazardous materials technician shall be able to:

4-4.2.1 Describe three safety procedures for personnel wearing vapor-protective clothing.

4-4.2.2* Describe three emergency procedures for personnel wearing vapor-protective clothing.

4-4.2.3* Identify the procedures for donning, working in, and doffing the following types of respiratory protection:

(a) Air line respirator with required escape unit

(b) Air purifying respirator

4-4.2.4 Demonstrate donning, working in, and doffing chemical-protective clothing in addition to any other specialized protective equipment provided by the authority having jurisdiction.

4-4.2.5 Demonstrate the ability to record the use, repair, and testing of chemical-protective clothing according to manufacturer's specifications and recommendations.

4-4.2.6 Describe the maintenance, testing, inspection, and storage procedures for personal protective equipment provided by the authority having jurisdiction according to the manufacturer's specifications and recommendations.

4-4.3 Performing Control Functions Identified in Plan of Action.

Given various simulated hazardous materials incidents involving nonbulk and bulk packaging and facility containers, the hazardous materials technician shall select the tools, equipment, and materials for the control of hazardous materials incidents and identify the precautions for controlling releases from those packaging/containers. The hazardous materials technician shall be able to:

4-4.3.1* Given a pressure vessel, select the appropriate material or equipment and demonstrate a method(s) to contain leaks from the following locations:

(a) Fusible metal of plug

(b) Fusible plug threads

(c) Side wall of cylinder

(d) Valve blowout

(e) Valve gland

(f) Valve inlet threads

(g) Valve seat

(h) Valve stem assembly blowout

4-4.3.2* Given the fittings on a pressure container, demonstrate the ability to perform the following:

(a) Close valves that are open

(b) Replace missing plugs

(c) Tighten loose plugs

4-4.3.3 Given a 55-gal (208-L) drum, demonstrate the ability to contain the following types of leaks using appropriate tools and materials:

(a) Bung leak

(b) Chime leak

(c) Forklift puncture

(d) Nail puncture

4-4.3.4 Given a 55-gal (208-L) drum and an overpack drum, demonstrate the ability to place the 55-gal drum into the overpack drum using the following methods:

(a) Rolling slide-in

(b) Slide-in

(c) Slip-over

4-4.3.5 Identify the maintenance and inspection procedures for the tools and equipment provided for the control of hazardous materials releases according to the manufacturer's specifications and recommendations.

4-4.3.6 Identify three considerations for assessing a leak or spill inside a confined space without entering the area.

4-4.3.7* Identify three safety considerations for product transfer operations.

4-4.3.8 Given an MC-306/DOT-406 cargo tank and a dome cover clamp, demonstrate the ability to install the clamp on the dome properly.

4-4.3.9 Identify the methods and precautions used when controlling a fire involving an MC-306/DOT-406 aluminum shell cargo tank.

4-4.3.10 Describe at least one method for containing each of the following types of leaks in MC-306/DOT-406, MC-307/DOT-407, and MC-312/DOT- 412 cargo tanks:

(a) Dome cover leak

(b) Irregular-shaped hole

(c) Puncture

(d) Split or tear

4-4.3.11* Describe three product removal and transfer considerations for overturned MC-306/DOT-406, MC-307/DOT-407, MC-312/DOT-412, MC-331, and MC-338 cargo tanks.

4-5 Competencies -- Evaluating Progress.

4-5.1 Evaluating the Effectiveness of the Control Functions.

Given various simulated facility and transportation hazardous materials incidents involving nonbulk and bulk packaging and the plan of action, the hazardous materials technician shall evaluate the effectiveness of any control functions identified in the plan of action.

4-6 Competencies -- Terminating the Incident.

4-6.1 Assisting in the Debriefing.

Given various simulated facility and transportation hazardous materials incidents involving nonbulk and bulk packaging, the hazardous materials technician shall participate in the debriefing of the incident. The hazardous materials technician shall be able to:

4-6.1.1 Describe three components of an effective debriefing.

4-6.1.2 Describe the key topics of an effective debriefing.

4-6.1.3 Describe when a debriefing should take place.

4-6.1.4 Describe who should be involved in a debriefing.

4-6.2 Assisting in the Incident Critique.

Given various simulated facility and transportation hazardous materials incidents involving nonbulk and bulk packaging, the hazardous materials technician shall provide operational observations of the activities that were performed in the hot and warm zones during the incident. The hazardous materials technician shall be able to:

4-6.2.1 Describe three components of an effective critique.

4-6.2.2 Describe who should be involved in a critique.

4-6.2.3 Describe why an effective critique is necessary after a hazardous materials incident.

4-6.2.4 Describe which written documents should be prepared as a result of the critique.

4-6.3 Providing Reports and Documentation.

Given a simulated hazardous materials incident, the hazardous materials technician shall complete the reporting and documentation requirements consistent with the organization's emergency response plan and standard operating procedures. The hazardous materials technician shall be able to:

4-6.3.1 Identify the reports and supporting documentation required by the local emergency response plan and the organization's standard operating procedures.

4-6.3.2 Demonstrate the proper completion of the reports required by the local emergency response plan and the organization's standard operating procedures.

4-6.3.3 Describe the importance of personnel exposure records.

4-6.3.4 Describe the importance of debriefing records.

4-6.3.5 Describe the importance of critique records.

4-6.3.6 Identify the steps in keeping an activity log and exposure records.

4-6.3.7 Identify the steps to be taken in compiling incident reports that meet federal, state, local, and organizational requirements.

4-6.3.8 Identify the requirements for compiling hot zone entry and exit logs.

4-6.3.9 Identify the requirements for compiling personal protective equipment logs.

4-6.3.10 Identify the requirements for filing documents and maintaining records.

Chapter 5 Competencies for the Incident Commander

5-1 General.

5-1.1 Introduction.

The incident commander shall be trained to meet all the competencies for the first responder awareness and operational levels and the competencies of this chapter. Incident commanders also shall receive any additional training to meet applicable United States Department of Transportation (DOT), United States Environmental Protection Agency (EPA), Occupational Safety and Health Administration (OSHA), and other appropriate state, local, or provincial occupational health and safety regulatory requirements.

5-1.2 Definition.

The incident commander is that person who is responsible for all decisions relating to the management of the incident. The incident commander is in charge of the incident site.

5-1.3* Goal.

The goal of this chapter shall be to provide the incident commander with the knowledge and skills to perform the following tasks safely. Therefore, in addition to being competent at the awareness and operational levels, the incident commander shall be able to:

(a) Analyze a hazardous materials incident to determine the magnitude of the problem in terms of outcomes by completing the following tasks:

1. Collect and interpret hazard and response information from printed resources, technical resources, computer data bases, and monitoring equipment

2. Estimate the potential outcomes within the endangered area at a hazardous materials incident

(b) Plan response operations within the capabilities and competencies of available personnel, personal protective equipment, and control equipment by completing the following tasks:

1. Identify the response objectives for hazardous materials incidents

2. Identify the potential action options (defensive, offensive, and nonintervention) available by response objective

3. Approve the level of personal protective equipment required for a given action option

4. Develop a plan of action, including safety considerations, consistent with the local emergency response plan and the organization's standard operating procedures and within the capability of available personnel, personal protective equipment, and control equipment

(c) Implement a response to favorably change the outcome consistent with the local emergency response plan and the organization's standard operating procedures by completing the following tasks:

1. Implement an incident management system (IMS), including the specified procedures for notification and utilization of nonlocal resources, e.g., private, state, and federal government personnel

2. Direct resources (private, governmental, and others) with expected task assignments and on-scene activities and provide management overview, technical review, and logistical support to private and governmental sector personnel

3. Provide a focal point for information transfer to media and local elected officials through the IMS structure

(d) Evaluate the progress of the planned response to ensure the response objectives are being met safely, effectively, and efficiently and adjust the plan of action accordingly by evaluating the effectiveness of the control functions

(e) Terminate the incident by completing the following tasks:

1. Transfer command (control) when appropriate

2. Conduct an incident debriefing

3. Conduct a multi-agency critique

4. Report and document the hazardous materials incident and submit the report to the proper entity

5-2 Competencies - Analyzing the Incident.

5-2.1 Collecting and Interpreting Hazard and Response Information.

Given access to printed and technical resources, computer data bases, and monitoring equipment, the incident commander shall collect and interpret hazard and response information not available from the current edition of the *North American Emergency Response Guidebook* or a material safety data sheet (MSDS). The incident commander shall be able to identify and interpret the types of hazard and response information available from each of the following resources and explain the advantages and disadvantages of each resource:

(a) Reference manuals

(b) Hazardous materials data bases

(c) Technical information centers

(d) Technical information specialists

(e) Monitoring equipment

5-2.2 Estimating Potential Outcomes.

Given simulated facility or transportation incidents involving hazardous materials, the surrounding conditions, and the predicted behavior of the container and its contents, the incident commander shall estimate the potential outcomes within the endangered area. The incident commander shall be able to:

5-2.2.1 Identify the steps for estimating the number of exposures within the endangered area.

5-2.2.2 Describe the following toxicological terms and exposure values and explain their significance in the risk assessment process:

(a) Parts per million (ppm)

(b) Parts per billion (ppb)

(c) Lethal dose (LD_{50})

(d) Lethal concentrations (LC_{50})

(e) Permissible exposure limit (PEL)

(f) Threshold limit value time-weighted average (TLV-TWA)

(g) Threshold limit value short-term exposure limit (TLV-STEL)

(h) Threshold limit value ceiling (TLV-C)

(i) Immediately dangerous to life and health value (IDLH)

5-2.2.3* Describe the following radiological materials terms and explain their significance in predicting the extent of health hazards and environmental impact in a hazardous materials incident:

(a) Types

(b) Measurement

(c) Protection

5-2.2.4 Identify two methods for predicting the areas of potential harm within the endangered area of a hazardous materials incident.

5-2.2.5 Identify the methods available to the organization for obtaining local weather conditions and predictions for short-term future weather changes.

5-2.2.6 Explain the basic toxicological principles relative to assessment and treatment of personnel exposed to hazardous materials, including the following:

(a) Acute and delayed toxicity (chronic)

(b) Routes of exposure to toxic materials

(c) Local and systemic effects

(d) Dose response

(e) Synergistic effects

5-3 Competencies - Planning the Response.

5-3.1 Identifying Response Objectives.

Given simulated facility and transportation hazardous materials incidents, the incident commander shall identify the possible action options (defensive, offensive, and nonintervention) by response objectives for each problem. The incident commander shall be able to describe the steps for determining response objectives (defensive, offensive, and nonintervention) given an analysis of a hazardous materials incident.

5-3.2 Identifying the Potential Action Options.

Given simulated facility and transportation hazardous materials incidents, the incident commander shall identify the possible action options (defensive, offensive, and non-intervention) by response objective for each problem. The incident commander shall be able to:

5-3.2.1

Identify the possible action options to accomplish a given response objective.

5-3.2.2 Identify the purpose of each of the following techniques for hazardous materials control:

(a) Adsorption

(b) Neutralization

(c) Overpacking

(d) Patching

(e) Plugging

5-3.3 Approving the Level of Personal Protective Equipment.

Given situations with known and unknown hazardous materials, the incident commander shall approve the appropriate personal protective equipment for the action options specified in the plan of action in each situation. The incident commander shall be able to:

5-3.3.1 Identify the four levels of chemical protection (EPA/NIOSH) and describe the equipment required for each level with the conditions under which each level is used.

5-3.3.2 Describe the following terms and explain their impact and significance on the selection of chemical- protective clothing:

(a) Degradation

(b) Penetration

(c) Permeation

5-3.3.3 Describe three safety considerations for personnel wearing vapor-protective, liquid splash-protective, and high temperature-protective clothing.

5-3.3.4 Identify the physical and psychological stresses that can affect users of personal protective equipment.

5-3.4 Developing a Plan of Action.

Given simulated facility and transportation hazardous materials incidents, the incident commander shall develop a plan of action consistent with the local emergency response plan and the organization's standard operating procedures that is within the capability of the available personnel, personal protective equipment, and control equipment. The incident commander shall be able to:

5-3.4.1 Identify the steps for developing a plan of action.

5-3.4.2 Identify the factors to be evaluated in selecting public protective actions including evacuation and sheltering in-place.

5-3.4.3 Given the local emergency response plan and/or the organization's standard operating procedures, identify which agency will perform the following:

(a) Receive the initial notification

(b) Provide secondary notification and activation of response agencies

(c) Make ongoing assessments of the situation

(d) Command on-scene personnel (incident management system)

(e) Coordinate support and mutual aid

(f) Provide law enforcement and on-scene security (crowd control)

(g) Provide traffic control and rerouting

(h) Provide resources for public safety protective action (evacuation or shelter in-place)

(i) Provide fire suppression services when appropriate

(j) Provide on-scene medical assistance (ambulance) and medical treatment (hospital)

(k) Provide public notification (warning)

(l) Provide public information (news media statements)

(m) Provide on-scene communications support

(n) Provide emergency on-scene decontamination when appropriate

(o) Provide operational-level hazard control services

(p) Provide technician-level hazard mitigation services

(q) Provide environmental remedial action ("cleanup") services

(r) Provide environmental monitoring

5-3.4.4 Identify the process for determining the effectiveness of an action option on the potential outcomes.

5-3.4.5 Identify the safe operating practices/procedures that are required to be followed at a hazardous materials incident.

5-3.4.5.1 Identify the importance of pre-incident planning relating to safety during responses to specific sites.

5-3.4.5.2 Identify the procedures for presenting a safety briefing prior to allowing personnel to work on a hazardous materials incident.

5-3.4.5.3* Identify at least three safety precautions associated with search and rescue missions at hazardous materials incidents.

5-3.4.5.4 Identify the advantages and limitations and describe an example where each of the following decontamination methods would be used:

(a) Absorption

(b) Adsorption

(c) Chemical degradation

(d) Dilution

(e) Disposal

(f) Evaporation

(g) Neutralization

(h) Solidification

(i) Vacuuming

(j) Washing

5-3.4.5.5* Identify the atmospheric and physical safety hazards associated with hazardous materials incidents involving confined spaces.

5-4 Competencies - Implementing the Planned Response.

5-4.1 Implementing the Incident Management System.

Given a copy of the local emergency response plan, the incident commander shall identify the requirements of the plan, including the required procedures for notification and utilization of nonlocal resources (private, state, and federal government personnel). The incident commander shall be able to:

5-4.1.1 Identify the role of the incident commander during an incident involving hazardous materials.

5-4.1.2 Identify the duties and responsibilities of the following hazardous materials branch functions within the incident management system:

(a) Backup

(b) Decontamination

(c) Entry

(d) Hazardous Materials Branch Management

(e) Hazardous Materials Branch Safety

(f) Information/research

(g) Reconnaissance

(h) Resources

5-4.1.3 Identify the steps for implementing the local and related emergency response plans as required under SARA Title III (EPCRA) Section 303 of the federal regulations or other state and local emergency response planning legislation.

5-4.1.4 Given the local emergency response planning documents, identify the elements of each of the documents.

5-4.1.5 Identify the elements of the incident management system necessary to coordinate response activities at hazardous materials incidents.

5-4.1.6 Identify the primary local, state, regional, and federal government agencies and identify the scope of their regulatory authority (including the regulations) pertaining to the production, transportation, storage, and use of hazardous materials and the disposal of hazardous wastes.

5-4.1.7 Identify the government agencies and private sector resources offering assistance during a hazardous materials incident and identify their role and the type of assistance or resources available.

5-4.2* Directing Resources (Private and Governmental).

Given a simulated hazardous materials incident and the necessary resources to implement the planned response, the incident commander shall demonstrate the ability to direct the resources in a safe and efficient manner consistent with the capabilities of those resources.

5-4.3 Providing a Focal Point for Information Transfer to Media and Elected Officials.

Given a simulated hazardous materials incident, the incident commander shall identify appropriate information to provide to the media and local, state, and federal officials. The incident commander shall be able to:

5-4.3.1 Identify the local policy for providing information to the media.

5-4.3.2 Identify the responsibilities of the public information officer at a hazardous materials incident.

5-5 Competencies - Evaluating Progress.

5-5.1 Evaluating Progress of the Plan of Action.

Given simulated facility and transportation hazardous materials incidents, the incident commander shall evaluate the progress of the plan of action to determine whether the efforts are accomplishing the response objectives. The incident commander shall be able to:

5-5.1.1 Identify the procedures for evaluating whether the action options are effective in accomplishing the objectives.

5-5.1.2 Identify the steps for comparing actual behavior of the material and the container to that predicted in the analysis process.

5-5.1.3 Determine the effectiveness of the following:

(a) Personnel being used

(b) Personal protective equipment

(c) Established control zones

(d) Decontamination process

5-6 Competencies - Terminating the Incident.

5-6.1 Transfering Command/Control.

Given the details of a simulated incident, the local emergency response plan, and the organization's standard operating procedures, the incident commander shall be able to:

5-6.1.1*

Identify the appropriate steps to be taken to transfer command/control of the incident.

5-6.1.2 Demonstrate the transfer of command/control.

5-6.2 Conducting a Debriefing.

Given the details of a simulated hazardous materials incident, the incident commander shall conduct a debriefing of the incident. The incident commander shall be able to:

5-6.2.1 Describe three components of an effective debriefing.

5-6.2.2 Describe the key topics in an effective debriefing.

5-6.2.3 Describe when a debriefing should take place.

5-6.2.4 Describe who should be involved in a debriefing.

5-6.2.5 Identify the procedures for conducting incident debriefings at a hazardous materials incident.

5-6.3 Conducting a Multi-Agency Critique.

Given details of a simulated multi-agency hazardous materials incident, the incident commander shall conduct a critique of the incident. The incident commander shall be able to:

5-6.3.1 Describe three components of an effective critique.

5-6.3.2 Describe who should be involved in a critique.

5-6.3.3 Describe why an effective critique is necessary after a hazardous materials incident.

5-6.3.4 Describe what written documents should be prepared as a result of the critique.

5-6.3.5 Implement the procedure for conducting a critique of the incident.

5-6.4 Reporting and Documenting the Hazardous Materials Incident.

Given a simulated hazardous materials incident, the incident commander shall demonstrate the ability to report and document the incident consistent with the local, state, and federal requirements. The incident commander shall be able to:

5-6.4.1 Identify the reporting requirements of the federal, state, and local agencies.

5-6.4.2 Identify the importance of documentation for a hazardous materials incident, including training records, exposure records, incident reports, and critique reports.

5-6.4.3 Identify the steps in keeping an activity log and exposure records for hazardous materials incidents.

5-6.4.4 Identify the requirements for compiling hazardous materials incident reports found in the local emergency response plan and the organization's standard operating procedures.

5-6.4.5 Identify the requirements for filing documents and maintaining records found in the local emergency response plan and the organization's standard operating procedures.

Chapter 6 Competencies for Private Sector Specialist Employees

6-1 General.

6-1.1 Introduction.

Private sector specialist employees are those persons who, in the course of their regular job duties, work with or are trained in the hazards of specific chemicals or containers within their organization's area of specialization. In response to emergencies involving hazardous materials in their organization's area of specialization, they could be called upon to provide technical advice or assistance to the incident commander relative to specific chemicals or containers for chemicals. Private sector specialist employees shall receive training or demonstrate competency in their area of specialization annually. Private sector specialist employees also shall receive any additional training to meet applicable United States Department of Transportation (DOT), Occupational Safety and Health Administration (OSHA), United States Environmental Protection Agency (EPA), and other appropriate state, local, or provincial occupational health and safety regulatory requirements.

Private sector specialist employees respond to hazardous materials incidents under different circumstances. They respond to incidents within their facility, in and outside their assigned work area, and outside their facility. Persons responding away from the facility or within the facility outside their assigned work area respond as a member of a hazardous materials response team or as a private sector specialist employee as outlined in this chapter. When responding to incidents away from their assigned work area, private sector specialist employees shall be permitted to perform only at the response level at which they have been trained.

Persons responding to a hazardous materials incident within their work area are not required to be trained to the levels specified by this chapter. Persons within their work area who have informed the incident management structure of an emergency as defined in the facility's emergency response plan; who have adequate personal protective equipment and adequate training in the procedures they are to perform; and who have employed the buddy system can take limited action in the danger area (e.g., turning a valve) before the emergency response team arrives. The limited action taken must be addressed in the emergency response plan. Once the emergency response team arrives, these persons shall be restricted to the actions that their training level allows and must operate under the incident command structure.

6-1.2 Scope.

This chapter will address competencies for the following private sector specialist employees:

(a) Private sector specialist employee C

(b) Private sector specialist employee B

(c) Private sector specialist employee A

6-2 Private Sector Specialist Employee C.

6-2.1 General.

6-2.1.1 Introduction. The private sector specialist employee C shall meet the competencies at the first responder awareness level (Chapter 2) relative to their organization's area of specialization and the additional competencies in Section 6-2 of this chapter.

6-2.1.2 Definition. The private sector specialist employee C is that person who responds to emergencies involving chemicals and/or containers within his or her organization's area of specialization. Consistent with the organization's emergency response plan and standard operating procedures, the private sector specialist employees C can be called upon to gather and record information, provide technical advice, and/or arrange for technical assistance. A private sector specialist employee C does not enter the hot or warm zone at an emergency.

6-2.1.3 Goal. The private sector specialist employee C shall be competent at the first responder awareness level relative to their organization's area of specialization. The private sector specialist employee C shall have the knowledge and skills to perform the following duties and tasks safely:

(a) Assist the incident commander in analyzing the magnitude of an emergency involving chemicals or containers for chemicals by completing the following tasks:

1. Provide information on the hazards and harmful effects of specific chemicals

2. Provide information on the characteristics of specific containers for chemicals

(b) Assist the incident commander in planning a response to an emergency involving chemicals or containers for chemicals by completing the following tasks:

1. Provide information on the potential response options for chemicals or containers for chemicals

6-2.2 Competencies - Analyzing the Incident.

6-2.2.1 Providing Information on the Hazards and Harmful Effects of Specific Chemicals. Given a specific chemical(s) used in his or her organization's area of specialization and the appropriate material safety data sheet (MSDS) or other appropriate resource, the private sector specialist employee C shall advise the incident commander of the chemical's hazards and harmful effects. The private sector specialist employee C shall be able to:

6-2.2.1.1 Identify the following hazard information from the material safety data sheet (MSDS) or other appropriate resource:

(a) Physical and chemical characteristics

(b) Physical hazards of the chemical (including fire and explosion hazards)

(c) Health hazards of the chemical

(d) Signs and symptoms of exposure

(e) Routes of entry

(f) Permissible exposure limits

(g) Reactivity hazards

(h) Environmental concerns

6-2.2.1.2 Identify how to contact CHEMTREC/CANUTEC/SETIQ.

6-2.2.1.3 Identify the resources available from CHEMTREC/CANUTEC/SETIQ.

6-2.2.1.4 Given their organization's emergency response plan and standard operating procedures, identify additional resources of hazard information, including a method of contact.

6-2.2.2 Providing Information on Characteristics of Specific Containers. Given examples of facility and transportation containers for chemicals in their organization's area of specialization, the private sector specialist employee C shall advise the incident commander of the characteristics of the containers. The private sector specialist employee C shall be able to:

6-2.2.2.1 Identify each container by name.

6-2.2.2.2 Identify the markings that differentiate one container from another.

6-2.2.2.3 Given their organization's emergency response plan and standard operating procedures, identify the resources available that can provide information about the characteristics of the container.

6-2.3 Competencies - Planning the Response.

6-2.3.1 Providing Information on Potential Response Options for Specific Chemicals. Given a specific chemical used in their organization's area of specialization and an appropriate material safety data sheet (MSDS) or other appropriate resource, the private sector specialist employee C shall advise the incident commander of the response information for that chemical by being able to:

6-2.3.1.1 Obtain the following response information:

(a) Precautions for safe handling, including hygiene practices, protective measures, and procedures for cleanup of spills/leaks

(b) Applicable control measures, including personal protective equipment

(c) Emergency and first aid procedures

6-2.3.1.2 Identify additional resources for obtaining response information.

6-3 Private Sector Specialist Employee B.

6-3.1 General.

6-3.1.1 Introduction. The private sector specialist employee B shall be trained to meet the competencies at the private sector specialist employee C level and the additional competencies in Section 6-3 of this chapter.

6-3.1.2* Definition. The level B private sector specialist employee is that person who, in the course of their regular job duties, works with or is trained in the hazards of specific chemicals or containers within their individual area of specialization. Because of their education, training, or work experience, the private sector specialist employee B can be called upon to respond to incidents involving these chemicals or containers. The private sector specialist employee B can be used to gather and record information, provide technical advice, and provide technical assistance (including work within the hot zone) at the incident consistent with their organization's emergency response plan and standard operating procedures and the local emergency response plan.

6-3.1.3* Goal. The goal of these competencies is to ensure that the private sector specialist employee B has the knowledge and skills to safely perform the duties and responsibilities assigned in their organization's emergency response plan and standard operating procedures. Therefore, within their individual area of specialization, the private sector specialist employee B shall be able to:

(a) Assist the incident commander in analyzing the magnitude of an incident involving chemicals or containers for chemicals by completing the following tasks:

1. Provide and interpret information on the hazards and harmful effects

2. Provide and interpret information on the characteristics of specific containers

3. Provide information on concentrations of chemicals from exposure monitoring, dispersion modeling, or any other predictive method

(b) Assist the incident commander in planning a response to an incident involving chemicals or containers for chemicals by completing the following tasks:

1. Provide information on the potential response options and their consequences for specific chemicals or containers for chemicals

2. Provide information on the personal protective equipment requirements for a specific chemical

3. Provide information on the decontamination methods for a specific chemical

4. Provide information on the federal/provincial regulations that relate to the handling and disposal of a specific chemical

5. Develop a plan of action (within the capabilities of the available resources), including safety considerations, for handling chemicals or containers for chemicals consistent with their organization's emergency response plan and standard operating procedures

(c) Implement the planned response, as developed with the incident commander, for chemicals or containers for chemicals, consistent with their organization's emergency response plan and standard operating procedures and within the capabilities of the available resources, by completing the following tasks:

1. Perform response options specified in the plan of action, as agreed upon with the incident commander and consistent with their organization's emergency response plan and standard operating procedures (within the capabilities of the available resources)

2. Don, work in, and doff personal protective equipment needed to implement the response options

(d) Assist the incident commander to evaluate the results of implementing the planned response by completing the following tasks:

1. Provide feedback on the effectiveness of the response options taken

2. Provide reporting and subsequent documentation of the incident involving chemicals as required

6-3.2 Competencies - Analyzing the Incident.

6-3.2.1 Providing and Interpreting Information on Hazards of Specific Chemicals. Given a specific chemical within their individual area of specialization and an appropriate material safety data sheet (MSDS) or other appropriate resource, the private sector specialist employee B shall advise the incident commander of the chemical's hazards and harmful effects and the potential consequences based on the incident. The private sector specialist employee B shall be able to:

6-3.2.1.1 Given a specific chemical, identify and interpret the following hazard information:

(a) Physical and chemical characteristics

(b) Physical hazards of the chemical (including fire and explosion hazards)

(c) Health hazards of the chemical

(d) Signs and symptoms of exposure

(e) Routes of entry

(f) Permissible exposure limits

(g) Reactivity hazards

(h) Environmental concerns

6-3.2.1.2 Given examples of specific chemicals and the appropriate resources (as identified in their organization's emergency response plan and standard operating procedures), predict the potential behavior of the chemicals based on the damage found, including the consequences of that behavior.

6-3.2.1.3 Identify the general types of hazard information available from the other resources identified in their organization's emergency response plan and standard operating procedures.

6-3.2.2 Providing Information on Characteristics of Specific Containers. Given a container for specific chemicals, the private sector specialist employee B shall advise the incident commander of the characteristics and potential behavior of that container. The private sector specialist employee B shall be able to:

6-3.2.2.1 Given examples of containers for specific chemicals, identify the purpose and operation of the closures found on those containers.

6-3.2.2.2 Given a chemical container, list the types of damage that could occur.

6-3.2.2.3 Given examples of containers for specific chemicals and the appropriate resources (as identified in their organization's emergency response plan and standard operating procedures), predict the potential behavior of the containers and the consequences, based on the damage found.

6-3.2.2.4 Given their organization's emergency response plan and standard operating procedures, identify resources (including a method of contact) knowledgeable in the design, construction, and damage assessment of containers for chemicals.

6-3.2.3 Providing Information on Concentrations of Chemicals. Given a chemical and the applicable monitoring equipment provided by their organization for that chemical or the available predictive capabilities (e.g., dispersion modeling, exposure modeling), the private sector specialist employee B shall advise the incident commander of the concentrations of the released chemical and the implications of that information to the incident. The private sector specialist employee B shall be able to:

6-3.2.3.1 Identify the appropriate monitoring equipment.

6-3.2.3.2 Use the appropriate monitoring equipment provided by their organization to determine the actual concentrations of a specific chemical.

6-3.2.3.3 Given information on the concentrations of a chemical, interpret the significance of that concentration information to the incident relative to the hazards and harmful effects of the chemical.

6-3.2.3.4 Demonstrate field calibration and testing procedures, as necessary, for the monitoring equipment provided by their organization.

6-3.2.3.5 Given their organization's emergency response plan and standard operating procedures, identify the resources (including a method of contact) capable of providing monitoring equipment, dispersion modeling, or monitoring services.

6-3.3 Competencies - Planning the Response.

6-3.3.1 Providing Information on Potential Response Options and Consequences for Specific Chemicals. Given specific chemicals or containers within their individual area of specialization and the appropriate resources, the private sector specialist employee B shall advise the incident commander of the potential response options and their consequences. The private sector specialist employee B shall be able to:

6-3.3.1.1 Given a specific chemical and an appropriate material safety data sheet (MSDS), identify and interpret the following response information:

(a) Precautions for safe handling, including hygiene practices, protective measures, and procedures for cleanup of spills or leaks

(b) Applicable control measures, including personal protective equipment

(c) Emergency and first aid procedures

6-3.3.1.2 Given their organization's emergency response plan and standard operating procedures, identify additional resources for interpreting response information for a chemical.

6-3.3.1.3 Describe the advantages and limitations of the potential response options for a specific chemical.

6-3.3.1.4 Given their organization's emergency response plan and standard operating procedures, identify resources (including a method of contact) capable of:

(a) Repairing containers for chemicals

(b) Removing the contents of containers for chemicals

(c) Cleanup and disposal of chemicals or containers for chemicals

6-3.3.2 Providing Information on Personal Protective Equipment Requirements. Given specific chemicals or containers for chemicals within their individual area of specialization and the appropriate resources, the private sector specialist employee B shall advise the incident commander of the appropriate personal protective equipment necessary for various response options. The private sector specialist employee B shall be able to:

6-3.3.2.1 Given a specific chemical and an appropriate material safety data sheet (MSDS), identify personal protective equipment, including the materials of construction, that will be compatible with that chemical.

6-3.3.2.2 Given their organization's emergency response plan and standard operating procedures, identify other appropriate resources (including a method of contact) capable of identifying the personal protective equipment that is compatible with a specific chemical.

6-3.3.2.3 Given an incident involving a specific chemical and the response options for that problem, determine whether the personal protective equipment provided by the organization is appropriate for the options presented.

6-3.3.3 Providing Information on Decontamination Methods. Given a specific chemical within their individual area of specialization and the available resources, the private sector specialist employee B shall identify appropriate decontamination methods for various response options. The private sector specialist employee B shall be able to:

6-3.3.3.1 Given a specific chemical and a material safety data sheet (MSDS) or other resource, obtain the potential methods for removing or neutralizing that chemical.

6-3.3.3.2 Given a specific chemical and a material safety data sheet (MSDS) or other resource, identify the circumstances under which disposal of contaminated equipment would be necessary.

6-3.3.3.3 Given their organization's emergency response plan and standard operating procedures, identify resources (including a method of contact) capable of identifying potential decontamination methods.

6-3.3.4 Providing Information on Handling and Disposal Regulations. Given a specific chemical within their area of specialization and the available resources, the private sector specialist employee B shall advise the incident commander of the federal or provincial regulations that relate to the handling, transportation, and disposal of that chemical. The private sector specialist employee B shall be able to:

6-3.3.4.1 Given a specific chemical and a material safety data sheet (MSDS) or other resource, identify federal or provincial regulations that apply to the handling, transportation, and disposal of that chemical.

6-3.3.4.2 Given a specific chemical and a material safety data sheet (MSDS) or other resource, identify the agencies (including a method of contact) responsible for compliance with the federal or provincial regulations that apply to the handling, transportation, and disposal of a specific chemical.

6-3.3.4.3 Given their organization's emergency response plan and standard operating procedures, identify resources for information pertaining to federal or provincial regulations relative to the handling and disposal of a specific chemical.

6-3.3.5 Developing a Plan of Action. Given a simulated incident involving chemicals or containers used in their individual area of specialization, the private sector specialist employee B shall (in conjunction with the incident commander) develop a plan of action, consistent with their organization's emergency response plan and standard operating procedures, for handling chemicals or containers in that incident. The plan of action developed shall be within the capabilities of the available resources and shall include safety considerations. The private sector specialist employee B shall be able to:

6-3.3.5.1 Given the organization's emergency response plan and standard operating procedures, identify the process for development of a plan of action, including safety considerations.

6-3.4 Competencies - Implementing the Planned Response.

6-3.4.1 Performing Response Options Specified in the Plan of Action. Given an assignment by the incident commander in their individual area of specialization, the private sector specialist employee B shall perform the assigned actions consistent with their organization's emergency response plan and standard operating procedures. The private sector specialist employee B shall be able to:

6-3.4.1.1 Perform assigned tasks consistent with their organization's emergency response plan and standard operating procedures and the available personnel, tools, and equipment (including personal protective equipment), including the following:

(a) Confinement activities

(b) Containment activities

(c) Product removal activities

6-3.4.1.2* Identify factors that can affect an individual's ability to perform the assigned tasks.

6-3.4.2 Using Personal Protective Equipment. Given an assignment within their individual area of specialization that is consistent with their organization's emergency response plan and standard operating procedures, the private sector specialist employee B shall be able to:

6-3.4.2.1 Don, work in, and doff the appropriate respiratory protection and protective clothing for the assigned tasks.

6-3.4.2.2 Identify the safety considerations for personnel wearing personal protective equipment, including:

(a) Buddy system

(b) Backup personnel

(c) Symptoms of heat and cold stress

(d) Limitations of personnel working in personal protective equipment

(e) Indications of material degradation of chemical-protective clothing

(f) Physical and psychological stresses on the wearer

(g) Emergency procedures and hand signals

6-3.4.2.3 Identify the procedures for cleaning, sanitizing, and inspecting personal protective equipment provided by the organization.

6-3.5 Competencies - Evaluating Progress.

6-3.5.1 Providing an Evaluation of the Effectiveness of Selected Response Options. Given an incident involving specific chemicals or containers for chemicals within their individual area of specialization, the private sector specialist employee B shall advise the incident commander of the effectiveness of the selected response options. The private sector specialist employee B shall be able to:

6-3.5.1.1 Identify the criteria for evaluating whether or not the selected response options are effective in accomplishing the objectives.

6-3.5.1.2 Identify the circumstances when it would be prudent to withdraw from a chemical incident.

6-3.5.2 Reporting and Documenting the Incident. Given a simulated incident involving chemicals or containers for chemicals used in their individual area of specialization, the private sector specialist employee B shall complete the reporting and subsequent documentation requirements consistent with their organization's emergency response plan and standard operating procedures. The private sector specialist employee B shall be able to:

6-3.5.2.1 Identify the importance of documentation (including training records, exposure records, incident reports, and critique reports) for an incident involving chemicals.

6-3.5.2.2 Identify the steps used in keeping an activity log and exposure records.

6-3.5.2.3 Identify the requirements for compiling incident reports.

6-3.5.2.4 Identify the requirements for compiling hot zone entry and exit logs.

6-3.5.2.5 Identify the requirements for compiling personal protective equipment logs.

6-3.5.2.6 Identify the requirements for filing documents and maintaining records.

6-4 Private Sector Specialist Employee A.

6-4.1 General.

6-4.1.1 Introduction. The private sector specialist employee A shall be trained to meet the competencies at the private sector specialist employee C level (Section 6-2 in this chapter) and hazardous materials technician level (Chapter 4) relative to the chemicals and containers used in their organization's area of specialization.

6-4.1.2 Definition. The private sector specialist employee A is that person who is specifically trained to handle incidents involving chemicals or containers for chemicals used in their organization's area of specialization. Consistent with their organization's emergency response plan and standard operating procedures, the private sector specialist employee A shall be able to analyze an incident involving chemicals within their organization's area of specialization, plan a response to that incident, implement the planned response within the capabilities of the resources available, and evaluate the progress of the planned response.

6-4.1.3 Goal. The goal of this level of competence is to ensure that the private sector specialist employee A has the knowledge and skills to safely perform the duties and responsibilities assigned in their organization's emergency response plan and standard operating procedures. Therefore, in addition to being competent at the private sector specialist employee C and the hazardous materials technician levels, the private sector specialist employee A shall be able to, in conjunction with the incident commander:

(a) Analyze an incident involving chemicals and containers for chemicals used in their organization's area of specialization to determine the magnitude of the incident by completing the following tasks:

1. Survey an incident involving chemicals and containers for chemicals, including the following:

a. Identify the containers involved

b. Identify or classify unknown materials

c. Verify the identity of the chemicals

2. Collect and interpret hazard and response information from printed resources, technical resources, computer data bases, and monitoring equipment for chemicals

3. Determine the extent of damage to containers of chemicals

4. Predict the likely behavior of the chemicals and containers for chemicals

5. Estimate the potential outcomes of an incident involving chemicals and containers for chemicals

(b) Plan a response (within the capabilities of available resources) to an incident involving chemicals and containers for chemicals used in their organization's area of specialization by completing the following tasks:

1. Identify the response objectives for an incident involving chemicals and containers for chemicals

2. Identify the potential action options for each response objective for an incident involving chemicals and containers for chemicals

3. Select the personal protective equipment required for a given response option for an incident involving chemicals and containers for chemicals

4. Select the appropriate decontamination procedures, as necessary, for an incident involving chemicals and containers for chemicals

5. Develop a plan of action (within the capabilities of the available resources), including safety considerations, for handling an incident involving chemicals and containers for chemicals consistent with their organization's emergency response plan and standard operating procedures

(c) Implement the planned response (as developed with the incident commander) to an incident involving chemicals and containers for chemicals used in their organization's area of specialization consistent with their organization's emergency response plan and standard operating procedures by completing the following tasks:

1. Don, work in, and doff appropriate personal protective equipment provided by their organization for use with chemicals

2. Perform control functions, as agreed upon with the incident commander, for chemicals and containers for chemicals

(d) Evaluate the results of implementing the planned response to an incident involving chemicals and containers for chemicals used in their organization's area of specialization

Chapter 7 Competencies for the Hazardous Materials Branch Officer

7-1 General.

7-1.1 Introduction.

The hazardous materials branch officer shall be trained to meet all competencies for the first responder at the awareness, operational, and technician levels and the competencies of this chapter. The hazardous materials branch officer also shall receive any additional training to meet applicable United States Department of Transportation (DOT), United States Environmental Protection Agency (EPA), Occupational Safety and Health Administration (OSHA), and other appropriate state, local, or provincial occupational health and safety regulatory requirements.

7-1.2

Definition. The hazardous materials branch officer is that person who is responsible for directing and coordinating all operations assigned to the hazardous materials branch by the incident commander.

7-1.3 Goal.

The goal of this chapter shall be to provide the hazardous materials branch officer with the knowledge and skills to perform the following tasks safely. Therefore, in addition to being competent at the awareness, operational, and technician levels, the hazardous materials branch officer shall be able to:

(a) Analyze a hazardous materials incident to determine the magnitude of the problem by estimating the potential outcomes within the endangered area

(b) Plan a response within the capabilities and competencies of available personnel, personal protective equipment, and control equipment by completing the following tasks:

1. Identify the response objectives for hazardous materials incidents

2. Identify the potential action options (defensive, offensive, and nonintervention) available by response objective

3. Determine the level of personal protective equipment required for a given action option

4. Provide recommendations to the incident commander for the development of a plan of action for the hazardous materials branch consistent with the local emergency response plan and the organization's standard operating procedures and within the capability of available personnel, personal protective equipment, and control equipment

(c) Implement a response to favorably change the outcomes consistent with the local emergency response plan and the organization's standard operating procedures by completing the following tasks:

1. Implement the incident management system as it directly relates to the specified procedures for hazardous materials branch operations

2. Direct hazardous materials branch resources (private, governmental, and others) with expected task assignments and on-scene activities and provide management overviews, technical review, and logistical support to hazardous materials branch resources

(d) Evaluate the progress of the planned response to ensure that the response objectives are being met safely, effectively, and efficiently and adjust the plan of action accordingly by evaluating the progress of the plan of action

(e) Terminate the incident by completing the following:

1. Conduct a debriefing for hazardous materials branch personnel

2. Conduct a critique for hazardous materials branch personnel

3. Report and document the hazardous materials branch operations

7-2 Competencies - Analyzing the Incident.

7-2.1 Estimating Potential Outcomes.

Given simulated facility or transportation incidents involving hazardous materials, the surrounding conditions, and the predicted behavior of the container and its contents, the hazardous materials branch officer shall estimate the potential outcomes within the endangered area.

7-3 Competencies - Planning the Response.

7-3.1 Selecting the Level of Personal Protective Equipment.

Given situations with known and unknown hazardous materials, the hazardous materials branch officer shall select the appropriate personal protective equipment for the action options specified in the plan of action in each situation.

7-3.2 Developing a Plan of Action.

Given simulated facility and transportation hazardous materials incidents, the hazardous materials branch officer shall develop a plan of action consistent with the local emergency response plan and the organization's standard operating procedures that is within the capability of the available personnel, personal protective equipment, and control equipment. The hazardous materials branch officer shall be able to:

7-3.2.1 Identify the order of the steps for developing a plan of action.

7-3.2.2 Identify the factors to be evaluated in selecting public protective actions, including evacuation and shelter in-place.

7-3.2.3 Given the local emergency response plan or the organization's standard operating procedure, identify procedures to accomplish the following tasks:

(a) Make ongoing assessments of the situation

(b) Command on-scene personnel (incident management system) assigned to the hazardous materials branch

(c) Coordinate hazardous materials support and mutual aid

(d) Provide resources for public protection action (evacuation or shelter in-place)

(e) Coordinate with fire suppression services as it relates to hazardous materials incidents

(f) Coordinate hazardous materials branch control, containment, or confinement operations

(g) Coordinate with the medical branch to ensure proper medical assistance (ambulance) and medical treatment (hospital)

(h) Coordinate on-scene decontamination when appropriate

(i) Coordinate activities with those of the environmental remedial action ("cleanup") services

7-3.2.4 Identify the process for determining the effectiveness of an action option on the potential outcomes.

7-3.2.5 Identify the procedures for presenting a safety briefing prior to allowing personnel to work on a hazardous materials incident.

7-4 Competencies - Implementing the Planned Response.

7-4.1 Implementing the Incident Management System.

Given a copy of the local emergency response plan, the hazardous materials branch officer shall identify the requirements of the plan, including the required procedures for notification and utilization of nonlocal resources (private, state, and federal government personnel). The hazardous materials branch officer shall be able to:

7-4.1.1 Identify the process and procedures for obtaining cleanup and restoration services in the local emergency response plan or organization's standard operating procedures.

7-4.1.2 Identify the steps for implementing the local and related emergency response plans as required under SARA Title III Section 303 of the federal regulations or other local emergency response planning legislation.

7-4.1.3 Given the local emergency planning documents, identify the elements of each of the documents.

7-4.1.4 Identify the elements of the incident management system necessary to coordinate response activities at hazardous materials incidents.

7-4.1.5 Identify the primary local, state, regional, and federal government agencies and identify the scope of their regulatory authority (including the regulations) pertaining to the production, transportation, storage, and use of hazardous materials and the disposal of hazardous wastes.

7-4.1.6 Identify the governmental agencies and private sector resources offering assistance to the hazardous materials branch during a hazardous materials incident and identify their role and type of assistance or resources available.

7-4.2* Directing Resources (Private and Governmental).

Given a simulated hazardous materials incident and the necessary resources to implement the planned response, the hazardous materials branch officer shall demonstrate the ability to direct the hazardous materials branch resources in a safe and efficient manner consistent with the capabilities of those resources.

7-4.3 Providing a Focal Point for Information Transfer to Media and Elected Officials.

Given a simulated hazardous materials incident, the hazardous materials branch officer shall demonstrate the ability to act as a resource to provide information to the incident commander or the public information officer for distribution to the media and local, state, and federal officials. The hazardous materials branch officer shall be able to:

7-4.3.1 Identify the local policy for providing information to the media.

7-4.3.2 Identify the responsibilities of the public information officer at a hazardous materials incident.

7-5 Competencies - Evaluating Progress.

7-5.1 Evaluating Progress of the Plan of Action.

Given simulated facility and transportation hazardous materials incidents, the hazardous materials branch officer shall evaluate the progress of the plan of action to determine whether the efforts are accomplishing the response objectives. The hazardous materials branch officer shall be able to:

7-5.1.1 Identify the procedures for evaluating whether the action options are effective in accomplishing the objectives.

7-5.1.2 Identify the steps for comparing actual behavior of the material and the container to that predicted in the analysis process.

7-5.1.3 Determine the effectiveness of the following:

(a) Hazardous materials response personnel being used

(b) Personal protective equipment

(c) Established control zones

(d) Control, containment, or confinement operations

(e) Decontamination process

7-6 Competencies - Terminating the Incident.

7-6.1 Terminating the Emergency Phase of the Hazardous Materials Incident.

Given a simulated hazardous materials incident, the hazardous materials branch officer shall demonstrate the ability to terminate the emergency phase of the incident consistent with the local emergency response plan and the organization's standard operating procedures. The hazardous materials branch officer shall be able to:

7-6.1.1 Identify the steps required in terminating the emergency phase of a hazardous materials incident.

7-6.1.2 Identify the procedures for conducting incident debriefings at a hazardous materials incident.

7-6.1.3 Identify the steps in transferring authority as prescribed in the local emergency response plan or the organization's standard operating procedures.

7-6.2 Conducting a Debriefing.

Given the details of a simulated hazardous materials incident, the hazardous materials branch officer shall demonstrate the ability to conduct a debriefing of the incident for all units assigned to the hazardous materials branch. The hazardous materials branch officer shall be able to:

7-6.2.1 Describe three components of an effective debriefing.

7-6.2.2 Describe the key topics in an effective debriefing.

7-6.2.3 Describe when a debriefing should take place.

7-6.2.4 Describe who should be involved in a debriefing.

7-6.2.5 Identify the procedures for conducting incident debriefings at a hazardous materials incident.

7-6.3 Conducting a Critique.

Given the details of a simulated hazardous materials incident, the hazardous materials branch officer shall demonstrate the ability to conduct a critique of the incident for all units assigned to the hazardous materials branch. The hazardous materials branch officer shall be able to:

7-6.3.1 Describe three components of an effective critique.

7-6.3.2 Describe who should be involved in a critique.

7-6.3.3 Describe why an effective critique is necessary after a hazardous materials incident.

7-6.3.4 Describe what written documents should be prepared as a result of the critique.

7-6.3.5 Identify the procedure for conducting a critique of the incident.

7-6.3.6 Identify the requirements for conducting a post-incident analysis as defined in the local emergency response plan, the organization's standard operating procedures, or federal, state, and local regulations.

7-6.4 Reporting and Documenting the Hazardous Materials Incident.

Given a simulated hazardous materials incident, the hazardous materials branch officer shall demonstrate the ability to report and document the incident consistent with the local, state, and federal requirements. The hazardous materials branch officer shall be able to:

7-6.4.1 Identify the reporting requirements of federal, state, and local agencies.

7-6.4.2 Identify the importance of documentation for a hazardous materials incident, including training records, exposure records, incident reports, and critique reports.

7-6.4.3 Identify the steps in keeping an activity log and exposure records for hazardous materials incidents.

7-6.4.4 Identify the requirements found in the local emergency response plan and the organization's standard operating procedures for compiling hazardous materials incident reports.

7-6.4.5 Identify the requirements for filing documents and maintaining records as defined in the local emergency response plan and the organization's standard operating procedures.

Chapter 8 Competencies for the Hazardous Materials Branch Safety Officer

8-1 General.

8-1.1* Introduction.

The hazardous materials branch safety officer shall be trained to meet all the competencies for the first responder at the awareness, operational, and technician levels and the competencies of this chapter. The hazardous materials branch safety officer also shall receive any additional training to meet applicable United States Department of Transportation (DOT), United States Environmental Protection Agency (EPA), Occupational Safety and Health Administration (OSHA), and other appropriate state, local, or provincial occupational health and safety regulatory requirements.

8-1.2* Definition.

The hazardous materials branch safety officer is that person who works within an incident management system (IMS) to ensure that recognized safe practices are followed within the hazardous materials branch. The hazardous materials branch safety officer will be called upon to provide technical advice or assistance regarding safety issues to the hazardous materials branch officer and incident safety officer at a hazardous materials incident.

8-1.3 Goal.

The goal of this chapter shall be to provide the hazardous materials branch safety officer with the knowledge and skills to evaluate a hazardous materials incident for safety and ensure that recognized safe operational practices are followed. Therefore, in addition to being knowledgeable at the level of operations being performed, the hazardous materials branch safety officer shall be able to:

(a) Analyze a hazardous materials incident to determine the magnitude of the problem in terms of safety by observing a scene and reviewing and evaluating hazard and response information as it pertains to the safety of all persons within the hazardous materials branch

(b) Assist in planning a safe response within the capabilities of available response personnel, personal protective equipment, and control equipment by completing the following tasks:

1. Identify the safety precautions for potential action options
2. Provide recommendations regarding safety considerations
3. Assist in the development of a plan of action
4. Review the plan of action and provide recommendations regarding safety
5. Review the selection of personal protective equipment required for a given action option
6. Review the decontamination operations

7. Ensure that the proper emergency medical services are provided

(c) Ensure the implementation of a safe planned response consistent with the local emergency response plan, the organization's standard operating procedures, and safety considerations by completing the following tasks:

1. Perform the duties of the hazardous materials branch safety officer within the local incident management system (IMS)

2. Identify safety considerations for personnel performing the control functions identified in the plan of action

3. Conduct safety briefings for personnel performing the control functions identified in the plan of action

4. Assist in the implementation and enforcement of safety considerations

5. Maintain communications within the incident command structure during the incident

6. Monitor status reports of activities in the hot and warm zones

7. Ensure the implementation of exposure monitoring (personnel and environment)

(d) Evaluate the progress of the planned response to ensure that the response objectives are being met safely by completing the following tasks:

1. Identify deviations from safety considerations and any dangerous situations

2. Alter, suspend, or terminate any activity that can be judged to be unsafe

(e) Assist in terminating the incident by completing the following tasks:

1. Perform the reporting, documentation and follow-up required of the hazardous materials branch safety officer

2. Assist in the debriefing of hazardous materials branch personnel

3. Assist in the incident critique

8-2 Competencies - Analyzing the Incident.

8-2.1 Determining the Magnitude of the Problem in Terms of Safety.

Given various simulated facility and transportation hazardous materials incidents involving nonbulk and bulk packaging, the hazardous materials branch safety officer shall observe a scene and review and evaluate hazard and response information as it pertains to the safety of all persons within the hazardous materials branch. The hazardous materials branch safety officer shall be able to:

8-2.1.1* Describe the following radioactive materials terms and explain their significance in predicting the extent of health hazards and environmental impact in a hazardous materials incident:

(a) Types

(b) Measurement

(c) Protection

8-2.1.2 Describe the following toxicological terms and exposure values and explain their significance in the risk assessment process:

(a) Parts per million (ppm)

(b) Parts per billion (ppb)

(c) Lethal dose (LD_{50})

(d) Lethal concentrations (LC_{50})

(e) Permissible exposure limit (PEL)

(f) Threshold limit value time-weighted average (TLV-TWA)

(g) Threshold limit value short-term exposure limit (TLV-STEL)

(h) Threshold limit value ceiling (TLV-C)

(i) Immediately dangerous to life and health value (IDLH)

8-2.1.3 Explain the basic toxicological principles relative to assessment and treatment of personnel exposed to hazardous materials, including the following:

(a) Acute and delayed toxicity

(b) Dose-response

(c) Local and systemic effects

(d) Routes of exposure to toxic materials

(e) Synergistic effects

8-2.1.4* Identify five conditions where the hazards from flammability would require chemical-protective clothing with thermal protection.

8-2.1.5* Identify five conditions where personnel would not be allowed to enter the hot zone.

8-2.1.6 Given the names of five hazardous materials and at least three reference sources, identify the physical and chemical properties and their potential impact on the safety of personnel at an incident involving each of the materials.

8-2.1.7 Given the names of five hazardous materials and at least three reference sources, identify the health concerns and their potential impact on the safety and health of personnel at an incident involving each of the materials.

8-2.1.8* Given the names of five hazardous materials and a description of their containers, identify five hazards or physical conditions that would impact the safety of personnel at an incident involving each of the materials.

8-2.1.9 Given at least three unknown materials, one of which is a solid, one a liquid, and one a gas, identify or classify by hazard each unknown material.

8-2.1.9.1 Identify steps in an analysis process for identifying unknown solid and liquid materials.

8-2.1.9.2 Identify steps in an analysis process for identifying an unknown atmosphere.

8-2.1.9.3 Identify the type(s) of monitoring equipment, test strips, and reagents used to determine the following hazards:

(a) Corrosivity (pH)

(b) Flammability

(c) Oxidation potential

(d) Oxygen deficiency

(e) Radioactivity

(f) Toxic levels

8-2.1.9.4* Identify the capabilities and limiting factors associated with the selection and use of the following monitoring equipment, test strips, and reagents:

(a) Carbon monoxide meter

(b) Colorimetric tubes

(c) Combustible gas indicator

(d) Oxygen meter

(e) Passive dosimeter

(f) Photoionization detectors

(g) pH indicators and/or pH meters

(h) Radiation detection instruments

(i) Reagents

(j) Test strips

8-2.1.9.5 Given three hazardous materials, one of which is a solid, one a liquid, and one a gas, and the following monitoring equipment, select and demonstrate the appropriate equipment to identify and quantify the materials:

(a) Carbon monoxide meter

(b) Colorimetric tubes

(c) Combustible gas indicator

(d) Oxygen meter

(e) pH papers and/or pH meters

(f) Radiation detection instruments

(g) Reagents

(h) Test strips

8-2.1.9.6 Demonstrate the field maintenance and testing procedures for the monitoring equipment, test strips and reagents provided by the authority having jurisdiction.

8-3 Competencies - Planning the Response.

8-3.1* Identifying the Safety Precautions for Potential Action Options.

Given various simulated facility and transportation hazardous materials incidents involving nonbulk and bulk packaging, the hazardous materials branch safety officer shall assist in planning a safe response within the capabilities of available response personnel, personal protective equipment, and control equipment. The hazardous materials branch safety officer shall be able to:

8-3.1.1* Identify five specific safety precautions to observe while mitigating each of the hazards or conditions identified in 8-2.1.8.

8-3.1.2* Identify five safety precautions associated with search and rescue missions at hazardous materials incidents.

8-3.2 Providing Recommendations Regarding Safety Considerations.

Given various simulated facility and transportation hazardous materials incidents involving nonbulk and bulk packaging, the hazardous materials branch safety officer shall provide the incident safety officer, hazardous materials branch officer, and incident commander with observation-based recommendations regarding considerations for the safety of on-site personnel. The hazardous materials branch safety officer shall be able to identify five recommendations to the incident commander regarding safety considerations on the hazards or conditions for each of the hazardous materials and containers identified in 8-2.1.8.

8-3.3 Assisting in the Development of a Plan of Action.

Given various simulated facility and transportation hazardous materials incidents involving nonbulk and bulk packaging, the hazardous materials branch safety officer shall assist the incident safety officer and hazardous materials branch officer in the development of a safe plan of action. The hazardous materials branch safety officer shall be able to:

8-3.3.1* Identify the importance and list five benefits of pre-emergency planning relating to specific sites.

8-3.3.2* Identify and name five hazards and precautions to be observed when approaching a hazardous materials incident.

8-3.3.3* List the elements of safety considerations.

8-3.3.4 Given an organizations pre-incident plan and a simulated hazardous materials incident involving one of the hazardous materials and containers described in 8-2.1.8, develop safety considerations for the incident.

8-3.4 Providing Recommendations Regarding Safety and Reviewing the Plan of Action.

Given a proposed plan of action for an incident involving one of the hazardous materials and containers described in 8-2.1.8, the hazardous materials branch safety officer shall identify to the incident safety officer, hazardous materials branch officer, and incident commander the safety precautions for the plan of action. The hazardous materials branch safety officer shall be able to:

8-3.4.1 Ensure that the safety considerations in the proposed plan of action are consistent with the local emergency response plan and the organization's standard operating procedures.

8-3.4.2 Make recommendations to the incident commander on the safety considerations in the proposed plan of action.

8-3.5 Reviewing Selection of Personal Protective Equipment.

Given various simulated facility and transportation hazardous materials incidents involving nonbulk and bulk packaging, the hazardous materials branch safety officer shall demonstrate the ability to review the selection of personal protective equipment required for a given action option. The hazardous materials branch safety officer shall be able to:

8-3.5.1 Identify the four levels of chemical protection (EPA/NIOSH) and describe the equipment required for each level and the conditions under which each level is used.

8-3.5.2 Identify five safety considerations for personnel wearing vapor-protective, liquid splash-protective, and high temperature-protective clothing.

8-3.5.3 Given the names of five different hazardous materials and a chemical compatibility chart for chemical-protective clothing, identify the chemical-protective clothing that would provide the appropriate protection to the wearer for each of the five substances.

8-3.5.4* Given the names of five different hazardous materials, identify appropriate chemical-protective clothing levels for typical action options.

8-3.5.5 Demonstrate proper methods for donning, doffing, and using all personal protective equipment provided by the authority having jurisdiction for use in hazardous materials response activities.

8-3.6 Reviewing the Proposed Decontamination Plan.

Given a site-specific decontamination plan by the hazardous materials branch officer or incident commander for a simulated hazardous materials incident, the hazardous materials branch safety officer shall review the plan to identify safety considerations prior to plan implementation. The hazardous materials branch safety officer shall be able to:

8-3.6.1 Identify the advantages and limitations and describe an example where each of the following decontamination methods would be used:

(a) Absorption

(b) Adsorption

(c) Chemical degradation

(d) Dilution

(e) Disposal

(f) Evaporation

(g) Neutralization

(h) Solidification

(i) Vacuuming

(j) Washing

8-3.6.2 Identify how personnel, personal protective equipment, apparatus, tools, and equipment become contaminated, as well as the importance and limitations of decontamination procedures.

8-3.6.3 Explain the need for decontamination procedures at hazardous materials incidents.

8-3.6.4 Identify three sources of technical information for selecting appropriate decontamination procedures and identify how to contact those sources in an emergency.

8-3.6.5 Identify the considerations associated with the placement, location, and setup of the decontamination corridor.

8-3.6.6 Identify the decontamination procedures as defined by the authority having jurisdiction for personnel and personal protective equipment at hazardous materials incidents.

8-3.6.7 Given three reference sources and a simulated hazardous materials incident involving two or more different chemicals, develop a site-specific personnel decontamination plan that is consistent with the local emergency response plan and the organization's standard operating guidelines.

8-3.7 Ensuring Provision of Proper Emergency Medical Services.

Given a simulated hazardous materials incident, the hazardous materials branch safety officer shall review the emergency medical services plan to ensure that response personnel are provided medical care. The hazardous materials branch safety officer shall be able to:

8-3.7.1* Identify the elements required in an emergency medical services plan.

8-3.7.2 Identify the importance of an on-site medical monitoring program.

8-3.7.3 Identify three resources for the transportation and care of the injured persons exposed to hazardous materials.

8-4 Competencies - Implementing the Planned Response.

8-4.1 Performing the Duties of the Hazardous Materials Branch Safety Officer.

Given various simulated facility and transportation hazardous materials incidents involving nonbulk and bulk packaging, the hazardous materials branch safety officer shall perform the duties of their position in a manner consistent with the local emergency response plan, the organization's standard operating procedures, and safety considerations. The hazardous materials branch safety officer shall be able to:

8-4.1.1 Identify the duties of the hazardous materials branch safety officer as defined in the organization's standard operating procedures.

8-4.1.2 Demonstrate proper performance of the duties of the hazardous materials branch safety officer as defined in the organization's standard operating procedures.

8-4.2 Monitoring Safety of Response Personnel.

Given a simulated hazardous materials incident and safety considerations, the hazardous materials branch safety officer shall ensure that personnel perform their tasks in a safe manner by identifying the safety considerations for the control functions identified in the plan of action. The hazardous materials branch safety officer shall be able to:

8-4.2.1 Identify the safe operating practices that are required to be followed at a hazardous materials incident as stated in the local emergency response plan and the organization's standard operating procedures.

8-4.2.2 Identify how the following factors influence heat and cold stress for hazardous materials response personnel:

(a) Activity levels

(b) Duration of entry

(c) Environmental factors

(d) Hydration

(e) Level of PPE

(f) Physical fitness

8-4.2.3 Identify the methods that will minimize the potential harm from heat and cold stress.

8-4.2.4 Identify the safety considerations that will minimize the psychological and physical stresses on personnel wearing vapor-protective, liquid splash-protective, and high temperature-protective clothing.

8-4.2.5 Describe five conditions where it would be prudent to withdraw from a hazardous materials incident.

8-4.3 Conducting Safety Briefings.

Given a simulated hazardous materials incident and safety considerations, the hazardous materials branch safety officer shall conduct safety briefings for personnel performing the control functions identified in the plan of action. The hazardous materials branch safety officer shall be able to demonstrate the proper procedure for conducting a safety briefing to personnel for an incident involving one of the hazardous materials and its container identified in 8-2.1.8, as specified by the organization's standard operating procedures.

8-4.4 Implementing and Enforcing Safety Considerations.

Given a simulated hazardous materials incident and safety considerations, the hazardous materials branch safety officer shall assist the incident commander, the incident safety officer, and the hazardous materials branch officer in implementing and enforcing the safety considerations. The hazardous materials branch safety officer shall be able to:

8-4.4.1 Identify whether the boundaries of the established control zones are clearly marked, consistent with the safety considerations, and are being maintained.

8-4.4.2 Identify whether the on-site medical monitoring that are required by the authority having jurisdiction is being performed.

8-4.4.3 Given an entry team, a backup team, and a decontamination team wearing personal protective clothing and equipment, identify that each team is properly protected and prepared to safely perform its assigned tasks.

8-4.4.3.1 Identify whether the selection of clothing and equipment is consistent with safety considerations.

8-4.4.3.2 Identify whether each team has examined the clothing for barrier integrity and the equipment to ensure proper working order.

8-4.4.3.3 Identify whether the protective clothing and equipment have been donned in accordance with the organization's standard operating procedures and the manufacturer's recommendations.

8-4.4.4 Identify whether each person entering the hot zone has a specific task assignment, understands the assignment, is properly trained to perform the assigned task(s), and is working with a designated partner at all times during the assignment.

8-4.4.5 Identify whether a backup team with the appropriate level of personal protective equipment is prepared at all times for immediate entry into the hot zone during entry team operations.

8-4.4.6 Identify whether the decontamination process specified in the safety considerations is in place before any entry into the hot zone.

8-4.4.7 Identify that each person exiting the hot zone and each tool or piece of equipment is decontaminated in accordance with the safety considerations and the degree of hazardous materials exposure.

8-4.4.8 Demonstrate the proper procedure for recording the names of the individuals exiting the hot zone, as specified in the local emergency response plan and the organization's standard operating procedures.

8-4.4.9* Identify three safety considerations that can minimize secondary contamination.

8-4.5 Maintaining Communications.

Given a simulated hazardous materials incident and the safety considerations, the hazardous materials branch safety officer shall maintain routine and emergency communications within the incident command structure at all times during the incident. The hazardous materials branch safety officer shall be able to:

8-4.5.1* Identify three types of communications systems used at hazardous materials incident sites.

8-4.5.2 Identify whether each person assigned to work in the hot zone understands the emergency alerting and response procedures specified in the safety considerations prior to entry into the hot zone.

8-4.6 Monitoring Status Reports.

Given a simulated hazardous materials incident and the safety considerations, the hazardous materials branch safety officer shall monitor routine and emergency communications within the incident command structure at all times during the incident. The hazardous materials branch safety officer shall be able to identify whether entry team members regularly communicate the status of their work assignment to the hazardous materials branch officer.

8-4.7 Implementing Exposure Monitoring.

Given a simulated hazardous materials incident and the safety considerations, the hazardous materials branch safety officer shall assist the incident commander, the incident safety officer, and the hazardous materials branch officer in implementing exposure monitoring.

8-4.8

The hazardous materials branch safety officer shall identify that exposure monitoring (personnel and environment) as specified in the organization's standard operating procedures and safety considerations is performed.

8-5 Competencies - Evaluating Progress.

8-5.1 Identifying Deviations from Safety Considerations and Any Dangerous Situations.

Given simulated facility and transportation hazardous materials incidents involving nonbulk and bulk packaging, and given simulated deviations from the safety considerations for activities in both the hot and warm zones and simulated dangerous conditions, the hazardous materials branch safety officer shall evaluate the progress of the planned response to ensure that the response objectives are being met safely. The hazardous materials branch safety officer shall be able to:

8-5.1.1 Identify those actions that deviate from the safety considerations or otherwise violate generally accepted safe operating practices, organizational policies, or applicable occupational safety and health laws, regulations, codes, standards, or guidelines.

8-5.1.2 Identify dangerous conditions that develop or are identified during work in the hot or warm zones that threaten the safety or health of persons in those zones.

8-5.1.3 Identify the signs and symptoms of psychological and physical stresses on personnel wearing vapor-protective, liquid splash-protective, and high temperature-protective clothing.

8-5.2 Taking Corrective Actions.

Given various simulated facility and transportation hazardous materials incidents involving nonbulk and bulk packaging, and given simulated deviations from the safety considerations for activities in both the hot and warm zones and simulated dangerous conditions, the hazardous materials branch safety officer shall take such corrective actions as are necessary to ensure the safety and health of persons in the hot and warm zones. The hazardous materials branch safety officer shall be able to:

8-5.2.1 Send emergency communications to, and receive emergency communications from, the incident safety officer, entry team personnel, the hazardous materials branch officer, and others as appropriate regarding safe working practices and conditions.

8-5.2.1.1* Given a hazardous situation or condition that has developed or been identified following initial hot zone entry, demonstrate the application of the emergency alerting procedures specified in the safety considerations to communicate the hazard and emergency response information to the affected personnel.

8-5.2.1.2 Given a demonstrated emergency alert via hand signal by a member of the entry team operating within the hot zone, identify the meaning of that signal as specified in the safety considerations.

8-5.2.2 Identify the procedures to alter, suspend, or terminate any activity that can be judged to be unsafe, as specified in the local emergency response plan and the organization's standard operating procedures.

8-5.2.3 Demonstrate the procedure for notifying the appropriate individual of the unsafe action and for directing alternative safe actions, in accordance with the safety considerations and the organization's standard operating procedures.

8-5.2.4 Demonstrate the procedure for suspending or terminating an action that could result in an imminent hazard condition, in accordance with the safety considerations and the organization's standard operating procedures.

8-6 Competencies - Terminating the Incident.

8-6.1 Providing Reports and Documentation.

Given various simulated facility and transportation hazardous materials incidents involving nonbulk and bulk packaging, the hazardous materials branch safety officer shall complete and submit the reports, documentation, and follow-up required of the hazardous materials branch safety officer. The hazardous materials branch safety officer shall be able to:

8-6.1.1 Identify the safety reports and supporting documentation required by the local emergency response plan and the organization's standard operating procedures.

8-6.1.2 Demonstrate the proper completion of the safety reports required by the local emergency response plan and the organization's standard operating procedures.

8-6.1.3 Describe the importance of personnel exposure records.

8-6.2 Debriefing of Hazardous Materials Branch Personnel.

Given various simulated facility and transportation hazardous materials incidents involving nonbulk and bulk packaging, the hazardous materials branch safety officer shall debrief hazardous materials branch personnel regarding site-specific occupational safety and health issues. The hazardous materials branch safety officer shall be able to:

8-6.2.1* Identify five health and safety topics to be addressed in an incident debriefing.

8-6.2.2 Demonstrate the proper procedure for debriefing hazardous materials branch personnel regarding site-specific occupational safety and health areas of concern, as specified in the safety considerations, local emergency response plan, and the organization's standard operating procedures.

8-6.3 Assisting in the Incident Critique.

Given various simulated facility and transportation hazardous materials incidents involving nonbulk and bulk packaging, the hazardous materials branch safety officer shall provide safety and health-related critical observations of the activities that were performed in the hot and warm zones during the incident.

8-6.4

Given the safety considerations and hazardous materials branch safety officer's report for a simulated incident, the hazardous materials branch safety officer shall demonstrate the proper procedure for verbally presenting the following in accordance with the local emergency response plan and the organization's standard operating procedures:

(a) Safety and health-related critical observations of the activities that were performed in the hot and warm zones during the incident

(b) Recorded violations of the safety considerations or generally accepted safe operating practices, organizational policies, or applicable occupational safety and health laws, regulations, codes, standards, or guidelines

(c) Injuries or deaths that occurred as a result of reasonably unforeseen dangerous conditions that developed during the incident

(d) Injuries or deaths that occurred as a result of violations of the safety considerations or generally accepted safe operating practices, organizational policies, or applicable occupational safety and health laws, regulations, codes, standards, or guidelines

(e) The proper course of action(s) that would likely have prevented the injuries or deaths that occurred as a result of the safety violations identified in (d)

(f) Deficiencies or weaknesses in the safety considerations, local emergency response plan, and organizational standard operating procedures that were noted during or following the incident

Chapter 9 Competencies for the Technician with a Tank Car Specialty

9-1 General.

9-1.1 Introduction.

Technicians with a tank car specialty shall meet all competencies of the first responder awareness, operational, and hazardous materials technician levels and the competencies of this chapter. The technician with a tank car specialty also shall receive any additional training to meet applicable United States Department of Transportation (DOT), United States Environmental Protection Agency (EPA), Occupational Safety and Health Administration (OSHA), and other appropriate state, local, or provincial occupational health and safety regulatory requirements.

9-1.2 Definition.

Technicians with a tank car specialty are those persons who provide support to the hazardous materials technician, provide oversight for product removal and movement of damaged tank cars, and act as a liaison between technicians and other outside resources. These technicians are expected to use specialized chemical-protective clothing and specialized control equipment.

9-1.3 Goals.

The goal of this chapter shall be to provide the technician with a tank car specialty with the knowledge and skills to perform the following tasks safely. In addition to being competent at the hazardous materials technician level, the technician with a tank car specialty shall be able to:

(a) Analyze a hazardous materials incident involving tank cars to determine the magnitude of the problem in terms of outcomes by completing the following tasks:

1. Determine the type and extent of damage to tank cars

2. Predict the likely behavior of tank cars and their contents in an emergency

(b) Plan a response for an emergency involving tank cars within the capabilities and competencies of available personnel, personal protective equipment, and control equipment by completing the following tasks:

1. Determine the response options (offensive, defensive, and nonintervention) for a hazardous materials emergency involving tank cars

2. Ensure that the options are within the capabilities and competencies of available personnel, personal protective equipment, and control equipment

(c) Implement the planned response to a hazardous materials incident involving tank cars

9-1.4 Mandating of Competencies.

This standard does not mandate that hazardous materials response teams performing offensive operations on tank cars have technicians with a tank car specialty. Technicians operating within the bounds of their training as listed in Chapter 4 of this standard are able to intervene in railroad incidents. However, if a hazardous materials response team desires to train some or all its technicians to have in-depth knowledge of tank cars, this chapter sets out the required competencies.

9-2 Competencies - Analyzing the Incident.

9-2.1 Determining the Type and Extent of Damage to Tank Cars.

Given examples of damaged tank cars, technicians with a tank car specialty shall describe the type and extent of damage to each tank car and its fittings. Technicians with a tank car specialty shall be able to:

9-2.1.1 Given the specification mark for a tank car and the appropriate reference materials, describe the car's basic construction and features.

9-2.1.2 Point out the "B" end of the car.

9-2.1.3 Given examples of various tank cars, point out and explain the design and purpose of each of the following tank car components, when present.

(a) Tank, including shell, and head

(b) Head shield

(c) Jacket

(d) Lining/cladding

(e) Heater coils - interior vs. exterior

(f) Underframe - continuous vs. stub sill

(g) Shelf couplers

(h) Body bolster

(i) Trucks (pin and bowl)

9-2.1.4 Given examples of tank cars (some jacketed; some not jacketed), point out the jacketed tank cars.

9-2.1.5 Describe the difference between "insulation" and "thermal protection" on tank cars.

9-2.1.6 Describe the difference between "jacketed" and "sprayed-on" thermal protection on tank cars.

9-2.1.7 Describe the difference between "interior" and "exterior" heater coils on tank cars.

9-2.1.8 Given examples of various fittings arrangements for pressure, nonpressure, cryogenic, and CO_2 tank cars (including examples of each of the following fittings), point out and explain the design, construction, and operation of each of the following fittings, when present:

(a) Fittings for loading and unloading tank cars, including the following:

1. Bottom outlet valves (top operated with stuffing box, bottom operated - internal or external ball, wafersphere)

2. Liquid valve/vapor valve (ball vs. plug type)

3. Excess flow valve

4. Air valve

5. Bottom outlet nozzle

6. Quick fill hole cover

7. Flange for manway, valves, etc.

8. CO_2 tank car fittings

9. Cryogenic liquid tank car fittings

(b) Fittings for pressure relief, including the following:

1. Safety relief devices (safety valve, safety vent, combination safety valve)

2. Pressure regulators on CO_2 cars and liquefied atmospheric gases in cryogenic liquid tank cars

3. Staged safety relief system for a CO_2 car

4. Vacuum relief valve (negative pressure or vacuum)

(c) Fittings for gauging, including the following:

1. Open gauging devices, e.g., slip tube

2. Closed gauging devices, e.g., magnetic

3. Other gauging devices (T-bar, long/short pole)

(d) Miscellaneous fittings, including the following:

1. Thermometer well

2. Sample line

3. Manway, manway cover plate, hinged and bolted manway cover, protective housing

4. Washout

5. Sump

9-2.1.9 Given examples of various fitting arrangements on tank cars (including CO_2 and cryogenic liquid tank cars) with the following fittings included, point out the location(s) where each fitting is likely to leak and a reason for the leak:

(a) Bottom outlet valve/top-operated bottom outlet valve (with stuffing box)

(b) Liquid valve/vapor valve (ball vs. plug type)

(c) Air valve

(d) Bottom outlet nozzle

(e) Quick fill hole cover

(f) Flange for manway, valves, etc.

(g) Safety relief valve

(h) Safety vent (with rupture/frangible) disk

(i) Combination safety valve

(j) Pressure regulators on CO_2 cars and liquefied atmospheric gases in cryogenic liquid tank cars

(k) Vacuum relief valve (negative pressure or vacuum)

(l) Open gauging devices, e.g., slip tube

(m) Closed gauging devices, e.g., magnetic

(n) Thermometer well

(o) Sample line

(p) Manway, manway cover plate, hinged and bolted manway cover, protective housing

(q) Washout

9-2.1.10 Given examples of each of the following types of tank car damage, identify the type of damage:

(a) Crack

(b) Score, gouge, wheel burn, rail burn

(c) Puncture

(d) Flame impingement

(e) Dent

(f) Corrosion

9-2.1.11* Given examples (actual or simulated) of scores, gouges, wheel burns, and rail burns, perform each of the following tasks:

(a) Use a depth gauge to measure the depth of each score, gouge, wheel burn, and rail burn

(b) Point out where each score, gouge, wheel burn, and rail burn crosses a weld, if that condition exists

(c) Measure the depth of the weld metal removed for any point where the score, gouge, wheel burn, and rail burn crosses a weld

(d) Given examples (actual or simulated) of where a score, gouge, wheel burn, and rail burn crosses a weld, determine if the "heat-affected zone" has been damaged

9-2.1.12 Given examples (actual or simulated) of dents and rail burns, perform each of the following tasks:

(a) Use a dent gauge to measure the radius of curvature for each dent or rail burn

(b) Identify those examples that include cracks at the point of minimum curvature

9-2.1.13 Given examples of damaged tank car fittings, describe the extent of damage to those fittings.

9-2.1.14 Given examples of tank car tank damage, describe the extent of damage to the tank car tank.

9-2.1.15 Given a tank car and the appropriate equipment and reference material, determine the pressure in the tank car, using either of the following methods:

(a) A pressure gauge

(b) The temperature of the contents

9-2.1.16* Given a tank car, use the car's gauging device to determine the amount of lading in it.

9-2.2 Predicting the Likely Behavior of the Tank Car and its Contents.

Technicians with a tank car specialty shall predict the likely behavior of the tank car and its contents. The technician with a tank car specialty shall be able to:

9-2.2.1 Given the following types of tank cars, describe the likely breach/release mechanisms associated with each type.

(a) Nonpressure tank cars

(b) Pressure tank cars

(c) Cryogenic liquid tank cars

(d) High-pressure tube cars

(e) Pneumatically unloaded covered hopper cars

9-2.2.2 Describe the difference in the following types of construction materials used in tank cars and their significance in assessing tank damage:

(a) Carbon steel

(b) Alloy steel

(c) Aluminum

9-2.2.3 Discuss the significance of selection of lading for compatibility with tank car construction material.

9-2.2.4 Describe the significance of "lining" and "cladding" on tank cars in assessing tank damage.

9-2.2.5 Describe the significance of the jacket on tank cars in assessing tank damage.

9-2.2.6 Describe the significance of "insulation" and "thermal protection" on tank cars in assessing tank damage.

9-2.2.7 Describe the significance of "jacketed" and "sprayed-on" thermal protection on tank cars in assessing tank damage.

9-2.2.8 Describe the significance of "interior" and "exterior" heater coils on tank cars in assessing tank damage.

9-2.2.9 Describe the significance of each of the following types of tank car damage on different types of tank cars in assessing tank damage:

(a) Crack

(b) Score, gouge, wheel burn, rail burn

(c) Puncture

(d) Flame impingement

(e) Dent

(f) Corrosion

9-2.2.10 Describe the significance of the depth of scores, gouges, wheel burns, and rail burns on tank cars in assessing tank damage.

9-2.2.11 Describe the significance of scores, gouges, wheel burns, and rail burns crossing a weld on a pressure tank car in assessing tank damage.

9-2.2.12 Describe the significance of damage to the "heat affected" zone of a weld on a tank car in assessing tank damage.

9-2.2.13 Describe the significance of a condemning dent of a tank car in assessing tank damage.

9-2.2.14 Given various types of tank cars, describe the significance of pressure increases in assessing tank damage.

9-2.2.15 Given various types of tank cars, describe the significance of the amount of lading in the tank in assessing tank damage.

9-2.2.16 Describe the significance of flame impingement on a tank car.

9-3 Competencies - Planning the Response.

9-3.1 Determining the Response Options.

Given the analysis of an emergency involving tank cars, technicians with a tank car specialty shall determine the response options for each tank car involved. The technician with a tank car specialty shall be able to:

9-3.1.1 Describe the purpose of, potential risks associated with, procedures for, equipment required to implement, and safety precautions for the following product removal techniques for tank cars:

(a) Transferring liquids and vapors

(b) Flaring liquids and vapors

(c) Venting

(d) Hot and cold tapping

(e) Vent and burn

9-3.1.2 Describe the inherent risks associated with, procedures for, equipment required to implement, and safety precautions for leak control techniques on various tank car fittings.

9-3.1.3 Describe the effect flaring or venting gas or liquid has on the pressure in the tank (flammable gas or flammable liquid product).

9-3.1.4 Describe the inherent risks associated with, procedures for, equipment required to implement, and safety precautions for lifting of tank cars.

9-3.1.5 Describe the inherent risks associated with, procedures for, and safety precautions for the following operations:

(a) Shutting off locomotives using the fuel shutoff and the battery disconnect

(b) Setting and releasing brakes on rail cars

(c) Uncoupling rail cars

9-3.1.6 Describe the hazards associated with working on railroad property during emergencies.

9-4 Competencies - Implementing the Planned Response.

9-4.1 Implementing the Planned Response.

Given an analysis of an emergency involving tank cars and the planned response, technicians with a tank car specialty shall implement or oversee the implementation of the selected response options safely and effectively. The technician with a tank car specialty shall be able to:

9-4.1.1 Given a leaking manway cover plate (loose bolts), control the leak.

9-4.1.2 Given leaking packing on the following tank car fittings, control the leak:

(a) Gauging device packing nut

(b) Liquid or vapor valve packing nut

(c) Top-operated bottom outlet valve packing gland

9-4.1.3 Given an open bottom outlet valve with a defective gasket in the cap, control the leak.

9-4.1.4 Given a leaking top-operated bottom outlet valve, close valve completely to control leak.

9-4.1.5 Given leaking fittings on a chlorine tank car, use the Chlorine C kit, as appropriate, to control the leak.

9-4.1.6 Given the following types of leaks on various types of tank cars, plug or patch those leaks:

(a) Puncture

(b) Irregular-shaped hole

(c) Cracks, splits, or tears

9-4.1.7 Given the appropriate equipment and resources, demonstrate the following:

(a) Transferring of liquids and vapors

(b) Flaring of liquids and vapors

(c) Venting

9-4.1.8 Given the appropriate resources, perform the following tasks:

(a) Shut off locomotives using the fuel shutoff and the battery disconnect

(b) Set and release brakes on rail cars

(c) Uncouple rail cars

9-4.1.9* Demonstrate bonding and grounding procedures for the transfer of flammable and combustible products from tank cars, or other products that can give off flammable gases or vapors when heated or contaminated, including the following:

(a) Selection of proper equipment

(b) Sequence of bonding and grounding connections

(c) Proper testing of bonding and grounding connections

9-4.1.10 Given a simulated flammable liquid spill from a tank car, describe the procedures for site safety and fire control during cleanup and removal operations.

Chapter 10 Competencies for the Technician with a Cargo Tank Specialty

10-1 General.

10-1.1 Introduction.

Technicians with a cargo tank specialty shall be trained to meet all competencies of the first responder awareness, operational, and hazardous materials technician levels and the competencies of this chapter. The technician with a cargo tank specialty also shall receive any additional training to meet applicable United States Department of Transportation (DOT), United States Environmental Protection Agency (EPA), Occupational Safety and Health Administration (OSHA), and other appropriate state, local, or provincial occupational health and safety regulatory requirements.

10-1.2 Definition.

Technicians with a cargo tank specialty are those persons who provide support to the hazardous materials technician, provide oversight for product removal and movement of damaged cargo tanks, and act as a liaison between technicians and other outside resources. These technicians are expected to use specialized chemical-protective clothing and specialized control equipment.

10-1.3 Goals.

The goal of this chapter shall be to provide the technician with a cargo tank specialty with the knowledge and skills to perform the following tasks safely. In addition to being competent at the technician level, the technician with a cargo tank specialty shall be able to:

(a) Analyze a hazardous materials incident involving cargo tanks to determine the magnitude of the problem in terms of outcomes by completing the following tasks:

1. Determine the type and extent of damage to cargo tanks

2. Predict the likely behavior of cargo tanks and their contents in an emergency

(b) Plan a response for an emergency involving cargo tanks within the capabilities and competencies of available personnel, personal protective equipment, and control equipment by determining the response options (offensive, defensive, and nonintervention) for a hazardous materials emergency involving cargo tanks

(c) Implement the planned response to a hazardous materials incident involving cargo tanks

10-1.4 Mandating of Competencies.

This standard does not mandate that hazardous materials response teams performing offensive operations on cargo tanks have technicians with a cargo tank specialty. Technicians operating within the bounds of their training as listed in Chapter 4 of this standard are able to intervene in cargo tank incidents. However, if a hazardous materials response team desires to train some or all its technicians to have in-depth knowledge of cargo tanks, this chapter sets out the required competencies.

10-2 Competencies - Analyzing the Incident.

10-2.1 Determining the Type and Extent of Damage to Cargo Tanks.

Given examples of damaged cargo tanks, technicians with a cargo tank specialty shall describe the type and extent of damage to each cargo tank and its fittings. The technician with a cargo tank specialty shall be able to:

10-2.1.1 Given the specification mark for a cargo tank and the appropriate reference materials, describe the tank's basic construction and features.

10-2.1.2 Given examples of cargo tanks (some jacketed; some not jacketed), point out the jacketed cargo tanks.

10-2.1.3 Given examples of the following types of cargo tank damage, identify the type of damage in each example:

(a) Crack

(b) Scrape, score, gouge, or loss of metal

(c) Puncture

(d) Dent

(e) Flame impingement

(f) Corrosion (internal/external)

10-2.1.4 Given simulated damage to an MC-331 cargo tank, determine the extent of damage to the heat-affected zone.

10-2.1.5* Given an MC-331 cargo tank containing a liquefied gas, determine the amount of liquid in the tank.

10-2.1.6 Given an MC-306/DOT-406, MC-307/DOT-407, and MC-312/DOT-412 cargo tank, point out and explain the design, construction, and operation of each of the following safety devices:

(a) Internal safety valve or external valve with accident protection, including method of activation (air, cable, hydraulic)

(b) Shear-type breakaway piping

(c) Emergency remote shutoff device

(d) Pressure and vacuum relief protection devices

(e) Dome cover design

10-2.1.7 Given an MC-331 and MC-338 cargo tank, point out and explain the design, construction, and operation of each of the following safety devices:

(a) Internal safety valve or external valve with accident protection, including method of activation (air, cable, hydraulic)

(b) Excess flow valve

(c) Fusible link and nut assemblies

(d) Emergency remote shutoff device

(e) Pressure relief protection devices

10-2.1.8 Given an MC-306/DOT-406 cargo tank, identify and describe the following normal methods of loading and unloading:

(a) Top loading

(b) Bottom loading

(c) Vapor recovery system

10-2.1.9 Given the following types of cargo tank trucks and tube trailer, identify and describe the normal methods of loading and unloading:

(a) MC-307/DOT-407

(b) MC-312/DOT-412

(c) MC-331

(d) MC-338

(e) Compressed gas tube trailer

10-2.1.10 Describe the normal and emergency methods of activation for the following types of cargo tank truck valve systems:

(a) Air

(b) Cable

(c) Hydraulic

10-2.1.11 Given a cargo tank involved in an emergency, identify the factors to be evaluated as part of the cargo tank damage assessment process, including the following:

(a) Type of cargo tank (MC or DOT specification)

(b) Pressurized or nonpressurized

(c) Number of compartments

(d) Type of tank metal (e.g., aluminum vs. stainless steel)

(e) Nature of the emergency (e.g., rollover, vehicle accident, struck by object, etc.)

(f) Container stress applied to the cargo tank

(g) Type and nature of tank damage (e.g., puncture, dome cover leak, valve failure, etc.)

(h) Amount of product both released and remaining in the cargo tank

10-2.2 Predicting the Likely Behavior of the Cargo Tank and its Contents.

Technicians with a cargo tank specialty shall predict the likely behavior of the cargo tank and its contents. The technician with a cargo tank specialty shall be able to:

10-2.2.1 Given the following types of cargo tanks (including a tube trailer), describe the likely breach/release mechanisms:

(a) MC-306/DOT-406 cargo tanks

(b) MC-307/DOT-407 cargo tanks

(c) MC-312/DOT-412 cargo tanks

(d) MC-331 cargo tanks

(e) MC-338 cargo tanks

(f) Compressed gas tube trailer

10-2.2.2 Describe the difference in types of construction materials used in cargo tanks and their significance in assessing tank damage.

10-2.2.3 Describe the significance of the jacket on cargo tanks in assessing tank damage.

10-2.2.4 Describe the significance of each of the following types of damage on different types of cargo tanks in assessing tank damage:

(a) Crack

(b) Scrape, score, gouge, or loss of metal

(c) Puncture

(d) Dent

(e) Flame impingement

(f) Corrosion (internal/external)

10-2.2.5 Given simulated damage to the heat-affected zone on a MC-331 cargo tank, describe the significance of the damage in assessing tank damage.

10-3 Competencies - Planning the Response.

10-3.1 Determining the Response Options.

Given the analysis of an emergency involving cargo tanks, technicians with a cargo tank specialty shall determine the response options for each cargo tank involved. The technician with a cargo tank specialty shall be able to:

10-3.1.1 Given an incident involving a cargo tank, describe the methods, procedures, risks, safety precautions, and equipment that are required to implement spill and leak control procedures.

10-3.1.2 Given an overturned cargo tank, describe the factors to be evaluated for uprighting, including the following:

(a) Type of cargo tank and material of construction

(b) Condition and weight of the cargo tank

(c) Type and nature of stress applied to the cargo tank

(d) Preferred lifting points

(e) Selection of lifting straps and/or air bags

(f) Lifting capabilities of wreckers and cranes

(g) Site safety precautions

10-4 Competencies - Implementing the Planned Response.

10-4.1 Implementing the Planned Response.

Given an analysis of an emergency involving a cargo tank and the planned response, technicians with a cargo tank specialty shall implement or oversee the implementation of the selected response options safely and effectively. The technician with a cargo tank specialty shall be able to:

10-4.1.1 Demonstrate the methods for containing the following leaks on liquid cargo tanks (e.g., MC-306/DOT-406, MC-307/DOT-407, and MC-312/DOT-412):

(a) Puncture

(b) Irregular-shaped hole

(c) Split or tear

(d) Dome cover leak

(e) Valves and piping

(f) Pressure relief devices (e.g., vents, burst disc, etc.)

10-4.1.2 Describe the methods for containing the following leaks in MC-331 and MC-338 cargo tanks:

(a) Crack

(b) Failure of safety relief device (e.g., relief valve, burst disc, etc.)

(c) Piping failure

10-4.1.3* Demonstrate bonding and grounding procedures for the transfer of flammable and combustible products from cargo tanks, or other products that can give off flammable gases or vapors when heated or contaminated, including the following:

(a) Selection of proper equipment

(b) Sequence of bonding and grounding connections

(c) Proper testing of bonding and grounding connections

10-4.1.4 Given the following product transfer and recovery equipment, demonstrate the safe and correct application and use of each of the following:

(a) Portable pumps (air, electrical, gasoline/diesel)

(b) Vehicles with power-take-off (PTO) driven pumps

(c) Pressure transfer

(d) Vacuum trucks

10-4.1.5 Given a simulated overturned MC-306/DOT-406 cargo tank, demonstrate the safe and proper procedures for the following methods of product removal and transfer:

(a) Drilling

(b) Unloading lines

(c) Vapor recovery lines

(d) Internal safety valve

10-4.1.6 Given a simulated overturned MC-307/DOT-407 cargo tank, demonstrate the safe and proper procedures for product removal and transfer.

10-4.1.7 Given a simulated overturned MC-331 cargo tank, demonstrate the safe and proper procedures for product removal and transfer.

10-4.1.8 Given the necessary resources, demonstrate the flaring of a MC-331 flammable gas cargo tank.

10-4.1.9 Given a simulated flammable liquid spill from a cargo tank, describe the procedures for site safety and fire control during cleanup and removal operations.

Chapter 11 Competencies for the Technician with an Intermodal Tank Specialty

11-1 General.

11-1.1 Introduction.

Technicians with an intermodal tank specialty shall be trained to meet all competencies of the first responder awareness, operational, and hazardous materials technician levels and the competencies of this chapter. The technician with an intermodal tank specialty also shall receive any additional training to meet applicable United States Department of Transportation (DOT), United States Environmental Protection Agency (EPA), Occupational Safety and Health Administration (OSHA), and other appropriate state, local, or provincial occupational health and safety regulatory requirements.

11-1.2 Definition.

Technicians with an intermodal tank specialty are those persons who provide support to the hazardous materials technician, provide oversight for product removal and movement of damaged intermodal tanks, and act as a liaison between technicians and other outside resources. These technicians are expected to use specialized chemical-protective clothing and specialized control equipment.

11-1.3 Goals.

The goal of this chapter shall be to provide the technician with an intermodal tank specialty with the knowledge and skills to perform the following tasks safely. In addition to being competent at the technician level, the technician with an intermodal tank specialty shall be able to:

(a) Analyze a hazardous materials incident involving an intermodal tank to determine the magnitude of the problem in terms of outcomes by completing the following tasks:

1. Determine the type and extent of damage to an intermodal tank
2. Predict the likely behavior of an intermodal tank and its contents in an emergency

(b) Plan a response for an emergency involving an intermodal tank within the capabilities and competencies of available personnel, personal protective equipment, and control equipment by determining the response options (offensive, defensive, and nonintervention) for a hazardous materials emergency involving intermodal tanks

(c) Implement the planned response to a hazardous materials incident involving intermodal tanks

11-1.4 Mandating of Competencies.

This standard does not mandate that hazardous materials response teams performing offensive operations on intermodal tanks have technicians with an intermodal tank specialty. Technicians operating within the bounds of their training as listed in Chapter 4 of this standard are able to intervene in intermodal tank incidents. However, if a hazardous materials response team desires to train some or all its technicians to have in-depth knowledge of intermodal tanks, this chapter sets out the required competencies.

11-2 Competencies - Analyzing the Incident.

11-2.1 Determining the Type and Extent of Damage to Intermodal Tanks.

Given examples of damaged intermodal tanks, technicians with an intermodal tank specialty shall describe the type and extent of damage to each intermodal tank and its fittings. The technician with an intermodal tank specialty shall be able to:

11-2.1.1 Given the specification mark for an intermodal tank and the appropriate reference materials, describe the tank's basic construction and features.

11-2.1.2 Given examples of intermodal tanks (some jacketed; some not jacketed), point out the jacketed intermodal tanks.

11-2.1.3 Given examples of various intermodal tanks, point out and explain the design and purpose of each of the following intermodal tank components, when present:

(a) Supporting frame

(b) Corner casting

(c) Insulation

(d) Jacket

(e) Heater coils (steam/electric)

(f) Refrigeration unit

(g) Data plate

11-2.1.4 Given examples of various fittings arrangements for pressure, nonpressure, and cryogenic intermodal tanks, point out and explain the design, construction, and operation of each of the following fittings, when present:

(a) Spill box

(b) Manhole cover

(c) Air line connection

(d) Top outlet

(e) Bottom outlet valve

(f) Thermometer

(g) Pressure gauge

(h) Gauging device

(i) Liquid or vapor valve

(j) Sample valve

(k) Thermometer well

11-2.1.5 Given examples of various safety devices for pressure, nonpressure, and cryogenic intermodal tanks, point out and explain the design, construction, and operation of each of the following safety devices, when present:

(a) Safety relief valve

(b) Regulator valve

(c) Rupture disc

(d) Fusible link/nut assemblies

(e) Emergency remote shutoff device

(f) Excess flow valve

11-2.1.6 Given the following types of intermodal tank damage, identify the type of damage in each example and explain its significance.

(a) Crack

(b) Puncture

(c) Dent

(d) Flame impingement

(e) Corrosion (internal/external)

(f) Metal loss (gouge/score)

11-2.1.7 Given three examples of damage to the framework of intermodal tanks, describe the damage in each example and explain its significance in the risk analysis process.

11-2.1.8 Given an intermodal tank involved in an emergency, identify the factors to be evaluated as part of the intermodal tank damage assessment process, including the following:

(a) Type of intermodal tank

(b) Pressurized or nonpressurized

(c) Number of compartments

(d) Type of tank metal

(e) Nature of the emergency

(f) Container stress applied to the intermodal tank

(g) Type and nature of tank damage

(h) Amount of product both released and remaining in the intermodal tank

11-2.1.9* Given a pressure intermodal tank containing a liquefied gas, determine the amount of liquid in the tank.

11-2.1.10* Given simulated damage to a pressure intermodal tank, determine the extent of damage to the heat-affected zone.

11-2.2 Predicting the Likely Behavior of the Intermodal Tank and its Contents.

Technicians with an intermodal tank specialty shall predict the likely behavior of the intermodal tank and its contents. The technician with an intermodal tank specialty shall be able to:

11-2.2.1 Given the following types of intermodal tanks, describe the likely breach/release mechanisms:

(a) IMO Type 1/IM-101

(b) IMO Type 2/IM-102

(c) IMO Type 5/DOT-51

(d) DOT-56

(e) DOT-57

(f) DOT-60

(g) Cryogenic (IMO Type 7)

11-2.2.2 Describe the difference in types of construction materials used in intermodal tanks relative to assessing tank damage.

11-3 Competencies - Planning the Response.

11-3.1 Determining the Response Options.

Given the analysis of an emergency involving intermodal tanks, technicians with an intermodal tank specialty shall determine the response options for each intermodal tank involved. The technician with an intermodal tank specialty shall be able to:

11-3.1.1 Describe the purpose of, potential risks associated with, procedures for, equipment required to implement, and safety precautions for the following product removal techniques for intermodal tanks:

(a) Transferring liquids and vapors (pressure/pump)

(b) Hot tapping

(c) Flaring liquids and vapors

11-3.1.2 Describe the purpose of, procedures for, and risks associated with controlling leaks from various fittings on intermodal tanks, including equipment needed and safety precautions.

11-4 Competencies - Implementing the Planned Response.

11-4.1 Implementing the Planned Response.

Given an analysis of an emergency involving intermodal tanks and the planned response, technicians with an intermodal tank specialty shall implement or oversee the implementation of the selected response options safely and effectively. The technician with an intermodal tank specialty shall be able to:

11-4.1.1 Given leaks from the following fittings on intermodal tanks, control the leaks using proper methods and procedures.

(a) Manway cover

(b) Bottom outlet

(c) Liquid/vapor valve

(d) Safety relief device

(e) Tank

11-4.1.2 Demonstrate proper procedures for the following types of emergency product removal:

(a) Gas/liquid transfer (pressure/pump)

(b) Flaring

(c) Venting

11-4.1.3* Demonstrate bonding and grounding procedures for the transfer of flammable and combustible products from an intermodal tank, or other products that can give off flammable gases or vapors when heated or contaminated, including the following:

(a) Selection of proper equipment

(b) Sequence of bonding and grounding connections

(c) Proper testing of bonding and grounding connections

11-4.1.4 Demonstrate the methods for containing the following leaks on liquid intermodal tanks (e.g., IM-101 and IM-102):

(a) Puncture

(b) Irregular-shaped hole

(c) Split or tear

(d) Dome cover leak

(e) Valves and piping

(f) Pressure relief devices (e.g., vents, burst disc, etc.)

11-4.1.5 Describe the methods for containing the following leaks in pressure intermodal tanks:

(a) Crack

(b) Failure of safety relief device (e.g., relief valve, burst disc, etc.)

(c) Piping failure

11-4.1.6 Given the following product transfer and recovery equipment, demonstrate the safe and correct application and use of the following:

(a) Portable pumps (air, electrical, gasoline/diesel)

(b) Vehicles with power-take-off (PTO) driven pumps

(c) Pressure transfer

(d) Vacuum trucks

11-4.1.7* Given a simulated overturned liquid intermodal tank, demonstrate the safe and proper procedures for product removal and transfer.

11-4.1.8* Given a simulated overturned pressure intermodal tank, demonstrate the safe and proper procedures for product removal and transfer.

11-4.1.9* Given the necessary resources, demonstrate the flaring of a pressure flammable gas intermodal tank.

11-4-1.10 Given a simulated flammable liquid spill from an intermodal tank, describe the procedures for site safety and fire control during cleanup and removal operations.

Chapter 12 Referenced Publications

12-1

The following documents or portions thereof are referenced within this standard as mandatory requirements and shall be considered part of the requirements of this standard. The edition indicated for each referenced mandatory document is the current edition as of the date of the

NFPA issuance of this standard. Some of these mandatory documents might also be referenced in this standard for specific informational purposes and, therefore, are also listed in Appendix D.

12-1.1 NFPA Publications.

National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.

NFPA 704, *Standard System for the Identification of the Hazards of Materials for Emergency Response*, 1996 edition.

NFPA 1561, *Standard on Fire Department Incident Management System*, 1995 edition.

NFPA 1991, *Standard on Vapor-Protective Suits for Hazardous Chemical Emergencies*, 1994 edition.

NFPA 1992, *Standard on Liquid Splash-Protective Suits for Hazardous Chemical Emergencies*, 1994 edition.

12-1.2 Other Publications.

12-1.2.1 U.S. Government Publications. U.S. Government Printing Office, Superintendent of Documents, Washington, DC 20402.

Title 29, *Code of Federal Regulations*, Part 1910.120

North American Emergency Response Guidebook, U.S. Department of Transportation, 1996 edition.

Appendix A Explanatory Material

This appendix is not a part of the requirements of this NFPA document but is included for informational purposes only.

A-1-1.2 Definitions of Responder Levels.

Awareness Level. First responders at the awareness level are those persons who, in the course of their normal duties, can be the first on the scene of an emergency involving hazardous materials. First responders at the awareness level are expected to recognize the presence of hazardous materials, protect themselves, call for trained personnel, and secure the area.

Operational Level. First responders at the operational level are those persons who respond to releases or potential releases of hazardous materials as part of the initial response to the incident for the purpose of protecting nearby persons, the environment, or property from the effects of the release. They should be trained to respond in a defensive fashion to control the release from a safe distance and keep it from spreading.

Technician Level. Hazardous materials technicians are those persons who respond to releases or potential releases of hazardous materials for the purpose of controlling the release. Hazardous materials technicians are expected to use specialized chemical protective clothing and specialized control equipment.

Command Level. The incident commander is that person who is responsible for all decisions relating to the management of the incident. The incident commander is in charge of the incident site.

List of Tasks by Responder Level

Analysis Tasks

(a) *Awareness Level.* The first responder at the awareness level should analyze an incident to determine both the hazardous materials present and the basic hazard and response information for each hazardous material by completing the following tasks:

1. Detect the presence of the hazardous materials

2. Survey a hazardous materials incident from a safe location to identify the name, UN/NA identification number, or type placard applied for any hazardous materials involved

3. Collect hazard and response information from the current edition of the *North American Emergency Response Guidebook*

(b) *Operational Level.* The first responder at the operational level should be competent at the awareness level and be able to analyze a hazardous materials incident to determine the magnitude of the problem in terms of outcomes by completing the following tasks:

1. Survey the hazardous materials incident to identify the containers and materials involved, determine whether hazardous materials have been released, and evaluate the surrounding conditions

2. Collect hazard and response information from material safety data sheets (MSDS), CHEMTREC/CANUTEC/SETIQ, and shipper/manufacturer contacts

3. Predict the likely behavior of a material and its container

4. Estimate the potential harm at a hazardous materials incident

(c) *Technician Level.* The hazardous materials technician should be competent at the awareness and operational level and be able to analyze a hazardous materials incident to determine the magnitude of the problem in terms of outcomes by completing the following tasks:

1. Survey the hazardous materials incident to identify special containers involved, to identify or classify unknown materials, and to verify the presence and concentrations of hazardous materials through the use of monitoring equipment

2. Collect and interpret hazard and response information from printed resources, technical resources, computer data bases, and monitoring equipment

3. Determine the extent of damage to containers

4. Predict the likely behavior of released materials and their containers when multiple materials are involved

5. Estimate the size of an endangered area using computer modeling, monitoring equipment, or specialists in this area

(d) *Command Level.* The incident commander should be competent to analyze a hazardous materials incident to determine the magnitude of the problem in terms of outcomes by completing the following tasks:

1. Collect and interpret hazard and response information from printed resources, technical resources, computer data bases, and monitoring equipment

2. Estimate the potential outcomes within the endangered area at a hazardous materials incident

Planning Tasks

(a) *Awareness Level.* No requirements.

(b) *Operational Level.* The first responder at the operational level should be competent at the first responder awareness level and be able to plan an initial response within the capabilities and competencies of available personnel, personal protective equipment, and control equipment by completing the following tasks:

1. Describe the response objectives for hazardous materials incidents

2. Describe the defensive options available by response objective

3. Determine if the personal protective equipment provided is appropriate for implementing each action option

4. Identify the emergency decontamination procedures

(c) *Technician Level.* The hazardous materials technician should be competent at both the first responder awareness and operational levels and be able to plan a response within the capabilities of available personnel, personal protective equipment, and control equipment by completing the following tasks:

1. Identify the response objectives for hazardous materials incidents

2. Identify the potential action options available by response objective

3. Select the personal protective equipment required for a given action option

4. Select the appropriate decontamination procedures

5. Develop a plan of action, including safety considerations, consistent with the local emergency response plan and the organization's standard operating procedures and within the capability of the available personnel, personal protective equipment, and control equipment

(d) *Command Level.* The incident commander should be competent to plan response operations within the capabilities and competencies of available personnel, personal protective equipment, and control equipment by completing the following tasks:

1. Identify the response objectives for hazardous materials incidents

2. Identify the potential action options (defensive, offensive, and nonintervention) available by response objective

3. Approve the level of personal protective equipment required for a given action option

4. Develop a plan of action, including safety considerations, consistent with the local emergency response plan and the organization's standard operating procedures and within the capability of available personnel, personal protective equipment, and control equipment

Implementation Tasks

(a) *Awareness Level.* The first responder at the awareness level should be able to implement actions consistent with the local emergency response plan, the organization's standard operating procedures, and the current edition of the *North American Emergency Response Guidebook* by completing the following tasks:

1. Initiate protective actions

2. Initiate the notification process

(b) *Operational Level.* The first responder at the operational level should be competent at the awareness level and be able to implement the planned response to favorably change the outcomes consistent with the local emergency response plan and the organization's standard operating procedures by completing the following tasks:

1. Establish and enforce scene control procedures, including control zones, decontamination, and communications

2. Initiate an incident management system (IMS)

3. Don, work in, and doff personal protective equipment provided by the authority having jurisdiction

4. Perform the defensive control actions identified in the plan of action

(c) *Technician Level.* The hazardous materials technician should be competent at both the first responder awareness and operational levels and be able to implement the planned response to favorably change the outcomes consistent with the organization's standard operating procedures or safety considerations by completing the following tasks:

1. Perform the duties of an assigned position within the local incident management system (IMS)

2. Don, work in, and doff appropriate personal protective clothing, including, but not limited to, both liquid splash- and vapor-protective clothing with appropriate respiratory protection

3. Perform the control functions identified in the plan of action

(d) *Command Level.* The incident commander should be competent at the operational level and be able to implement a response to favorably change the outcomes consistent with the local emergency response plan and the organization's standard operating procedures by completing the following tasks:

1. Implement the incident management system, including the specified procedures for notification and utilization of nonlocal resources (including private, state, and federal government personnel)

2. Direct resources (private, governmental, and others) with expected task assignments and on-scene activities, provide management overview, technical review, and logistical support to private and governmental sector personnel

3. Provide a focal point for information transfer to media and local elected officials through

the IMS structures

Evaluation Tasks

(a) *Awareness Level.* No requirements.

(b) *Operational Level.* The first responder at the operational level should be competent at the awareness level and be able to evaluate the progress of the actions taken to ensure that the response objectives are being met safely, effectively, and efficiently by completing the following tasks:

1. Evaluate the status of the defensive actions taken in accomplishing the response objectives
2. Communicate the status of the planned response

(c) *Technician Level.* The hazardous materials technician should be competent in evaluating the progress of the planned response by evaluating the effectiveness of the control functions.

(d) *Command Level.* The incident commander should be competent at the operational level and be able to evaluate the progress of the planned response to ensure the response objectives are being met safely, effectively, and efficiently and adjust the plan of action accordingly by evaluating the effectiveness of the control functions.

Termination Tasks

(a) *Awareness Level.* No requirements.

(b) *Operational Level.* No requirements.

(c) *Technician Level:* The hazardous materials technician should be competent to terminate an incident by completing the following tasks:

1. Assist in the incident debriefing
2. Assist in the incident critique
3. Provide reports and documentation of the incident

(d) *Command Level:* The incident commander should be competent to terminate an incident by completing the following tasks:

1. Transfer of command (control) when appropriate
2. Conduct an incident debriefing
3. Conduct a multi-agency critique
4. Report and document the hazardous materials incident and submit the reports to the proper entity

A-1-2 Approved. The National Fire Protection Association does not approve, inspect, or certify any installations, procedures, equipment, or materials; nor does it approve or evaluate testing laboratories. In determining the acceptability of installations, procedures, equipment, or materials, the authority having jurisdiction may base acceptance on compliance with NFPA or other appropriate standards. In the absence of such standards, said authority may require evidence of proper installation, procedure, or use. The authority having jurisdiction may also refer to the listings or labeling practices of an organization that is concerned with product evaluations and is thus in a position to determine compliance with appropriate standards for the current production of listed items.

A-1-2 Authority Having Jurisdiction. The phrase "authority having jurisdiction" is used in NFPA documents in a broad manner, since jurisdictions and approval agencies vary, as do their responsibilities. Where public safety is primary, the authority having jurisdiction may be a federal, state, local, or other regional department or individual such as a fire chief; fire marshal; chief of a fire prevention bureau, labor department, or health department; building official; electrical inspector; or others having statutory authority. For insurance purposes, an insurance inspection department, rating bureau, or other insurance company representative may be the authority having jurisdiction. In many circumstances, the property owner or his or her designated agent assumes the role of the authority having jurisdiction; at government installations, the commanding officer or departmental official may be the authority having jurisdiction.

A-1-2 Hazardous Material. There are many definitions and descriptive names being used for the term hazardous material, each of which depends on the nature of the problem being addressed.

Unfortunately, there is no one list or definition that covers everything. The U.S. agencies involved, as well as state and local governments, have different purposes for regulating hazardous materials that, under certain circumstances, pose a risk to the public or the environment.

Hazardous Materials. The U.S. Department of Transportation (DOT) uses the term *hazardous materials* to cover 11 hazard classes, some of which have subcategories called divisions. DOT includes in its regulations hazardous substances and hazardous wastes as Class 9 (Miscellaneous Hazardous Materials), both of which are regulated by the U.S. Environmental Protection Agency (EPA), if their inherent properties would not otherwise be covered.

Hazardous Substances. EPA uses the term *hazardous substances* for chemicals that, if released into the environment above a certain amount, must be reported, and, depending on the threat to the environment, federal involvement in handling the incident can be authorized. A list of the hazardous substances is published in Title 40, *Code of Federal Regulations,* Part 302, Table 302.4. The U.S. Occupational Safety and Health Administration (OSHA) uses the term *hazardous substance* in Title 29, *Code of Federal Regulations*, Part 1910.120, which resulted from Title I of Superfund Amendments and Reauthorization Act (SARA) and covers emergency response. OSHA uses the term differently than EPA. Hazardous substances, as used by OSHA, cover every chemical regulated by both DOT and EPA.

Extremely Hazardous Substances. EPA uses the term *extremely hazardous substances* for chemicals that must be reported to the appropriate authorities if released above the threshold reporting quantity. Each substance has a threshold reporting quantity. The list of extremely hazardous substances is identified in Title III of SARA of 1986 (Title 40, *Code of Federal Regulations*, Part 355).

Toxic Chemicals. EPA uses the term *toxic chemicals* for chemicals whose total emissions or releases must be reported annually by owners and operators of certain facilities that manufacture, process, or otherwise use a listed toxic chemical. The list of toxic chemicals is identified in Title III of SARA.

Hazardous Wastes. EPA uses the term *hazardous wastes* for chemicals that are regulated under the Resource, Conservation, and Recovery Act (Title 40, *Code of Federal Regulations*, Part 261.33). Hazardous wastes in transportation are regulated by DOT (Title 49, *Code of Federal Regulations*, Parts 170-179).

Hazardous Chemicals. OSHA uses the term *hazardous chemicals* to denote any chemical that would be a risk to employees if exposed in the workplace. Hazardous chemicals cover a broader group of chemicals than the other chemical lists.

Dangerous Goods. In Canadian transportation, hazardous materials are called *dangerous goods*.

Highly Hazardous Chemicals. OSHA uses the term *highly hazardous chemicals* for those chemicals that fall under the requirements of Title 29, *Code of Federal Regulations*, Part 1910.119, "Process Safety Management of Highly Hazardous Chemicals." *Highly hazardous chemicals* are those chemicals that possess toxic, reactive, flammable, or explosive properties. A list of covered substances is published in Appendix A of the OSHA rule.

A-1-2 Incident Management System. For more information, see NFPA 1561, *Standard on Fire Department Incident Management System.*

A-1-2 Listed. The means for identifying listed equipment may vary for each organization concerned with product evaluation; some organizations do not recognize equipment as listed unless it is also labeled. The authority having jurisdiction should utilize the system employed by the listing organization to identify a listed product.

A-1-2 Planned Response. The following site safety plan considerations are referenced from the Standard Operating Safety Guides, EPA, June 1992:

(a) Site description

(b) Entry objectives

(c) On-site organization

(d) On-site control

(e) Hazard evaluations

(f) Personal protective equipment

(g) On-site work plans

(h) Communication procedures

(i) Decontamination procedures

(j) Site safety and health plan

A-2-2.1.1 See A-1-2 Hazardous Material.

A-2-2.1.2, A-2-2.1.3 Definitions of Department of Transportation Hazard Classes and

Divisions. Title 49, *Code of Federal Regulations*, Parts 170-180.

Class 1 (Explosives)

An explosive is any substance or article, including a device, that is designed to function by explosion (i.e., an extremely rapid release of gas and heat) or that, by chemical reaction within itself, is able to function in a similar manner even if not designed to function by explosion. Explosives in Class 1 are divided into six divisions. Each division will have a letter designation.

Division 1.1 consists of explosives that have a mass explosion hazard. A mass explosion is one that affects almost the entire load instantaneously.

Examples of Division 1.1 explosives include black powder, dynamite, and TNT.

Division 1.2 consists of explosives that have a projection hazard but not a mass explosion hazard.

Examples of Division 1.2 explosives include aerial flares, detonating cord, and power device cartridges.

Division 1.3 consists of explosives that have a fire hazard and either a minor blast hazard or a minor projection hazard, or both, but not a mass explosion hazard.

Examples of Division 1.3 explosives include liquid-fueled rocket motors and propellant explosives.

Division 1.4 consists of explosive devices that present a minor explosion hazard. No device in the division may contain more than 25 g (0.9 oz) of a detonating material. The explosive effects are largely confined to the package and no projection of fragments of appreciable size or range are expected. An external fire must not cause virtually instantaneous explosion of almost the entire contents of the package.

Examples of Division 1.4 explosives include line-throwing rockets, practice ammunition, and signal cartridges.

Division 1.5 consists of very insensitive explosives. This division is comprised of substances that have a mass explosion hazard but are so insensitive that there is very little probability of initiation or of transition from burning to detonation under normal conditions of transport.

Examples of Division 1.5 explosives include pilled ammonium nitrate fertilizer-fuel oil mixtures (blasting agents).

Division 1.6 consists of extremely insensitive articles that do not have a mass explosive hazard. This division is comprised of articles that contain only extremely insensitive detonating substances and that demonstrate a negligible probability of accidental initiation or propagation.

Class 2 (Gases)

Division 2.1 (flammable gas) consists of any material that is a gas at 20ºC (68ºF) or less and 101.3 kPa (14.7 psi) of pressure, a material that has a boiling point of 20ºC (68ºF) or less at

101.3 kPa (14.7 psi), and that:

(a) Is ignitable at 101.3 kPa (14.7 psi) when in a mixture of 13 percent or less by volume with air

(b) Has a flammable range at 101.3 kPa (14.7 psi) with air of at least 12 percent regardless of the lower limit

Examples of Division 2.1 gases include inhibited butadienes, methyl chloride, and propane.

Division 2.2 (nonflammable, nonpoisonous compressed gas, including compressed gas, liquefied gas, pressurized cryogenic gas, and compressed gas in solution) consists of any material (or mixture) that exerts in the packaging an absolute pressure of 280 kPa (41 psia) at 20ºC (68ºF).

A cryogenic liquid is a refrigerated liquefied gas having a boiling point colder than -90ºC (-130ºF) at 101.3 kPa (14.7 psi) absolute.

Examples of Division 2.2 gases include anhydrous ammonia, cryogenic argon, carbon dioxide, and compressed nitrogen.

Division 2.3 (poisonous gas) consists of a material that is a gas at 20ºC (68ºF) or less and a pressure of 101.3 kPa (14.7 psi or 1 atm), a material that has a boiling point of 20ºC (68ºF) or less at 101.3 kPa (14.7 psi), and that:

(a) Is known to be so toxic to humans as to pose a hazard to health during transportation

(b) In the absence of adequate data on human toxicity, is presumed to be toxic to humans because, when tested on laboratory animals, it has an LC_{50} value of not more than 5,000 ppm

Examples of Division 2.3 gases include anhydrous hydrogen fluoride, arsine, chlorine, and methyl bromide.

Hazard zones associated with Division 2.3 materials are the following:

(a) Hazard zone A - LC_{50} less than or equal to 200 ppm

(b) Hazard zone B - LC_{50} greater than 200 ppm and less than or equal to 1,000 ppm

(c) Hazard zone C - LC_{50} greater than 1,000 ppm and less than or equal to 3,000 ppm

(d) Hazard zone D - LC_{50} greater than 3,000 ppm and less than or equal to 5,000 ppm

Class 3 (Flammable Liquid)

Flammable liquid is any liquid having a flash point of not more than 60.5ºC (141ºF).

Examples of Class 3 liquids include acetone, amyl acetate, gasoline, methyl alcohol, and toluene.

Combustible Liquid

Combustible liquid is any liquid that does not meet the definition of any other hazard class and has a flash point above 60ºC (140ºF) and below 93ºC (200ºF). Flammable liquids with a flash point above 38ºC (100ºF) can be reclassified as a combustible liquid.

Examples of combustible liquids include mineral oil, peanut oil, and No. 6 fuel oil.

Class 4 (Flammable Solids)

Division 4.1 (flammable solid) consists of any of the following three types of materials:

(a) Wetted explosives - explosives wetted with sufficient water, alcohol, or plasticizers to suppress explosive properties

(b) Self-reactive materials - materials that are liable to undergo, at normal or elevated temperatures, a strongly exothermic decomposition caused by excessively high transport temperatures or by contamination

(c) Readily combustible solids - solids that can cause a fire through friction and any metal powders that can be ignited

Examples of Division 4.1 materials include magnesium (pellets, turnings, or ribbons) and nitrocellulose.

Division 4.2 (spontaneously combustible material) consists of any of the following materials:

(a) Pyrophoric material - a liquid or solid that, even in small quantities and without an external ignition source, can ignite within five minutes after coming in contact with air

(b) Self-heating material - a material that, when in contact with air and without an energy supply, is liable to self-heat

Examples of Division 4.2 materials include aluminum alkyls, charcoal briquettes, magnesium alkyls, and phosphorus.

Division 4.3 (dangerous when wet material) consists of materials that, by contact with water, are liable to become spontaneously flammable or to give off flammable or toxic gas at a rate greater than 1 L/kg of the material per hour.

Examples of Division 4.3 materials include calcium carbide, magnesium powder, potassium metal alloys, and sodium hydride.

Class 5 (Oxidizers and Organic Peroxides)

Division 5.1 (oxidizer) consists of materials that can, generally by yielding oxygen, cause or enhance the combustion of other materials.

Examples of Division 5.1 materials include ammonium nitrate, bromine trifluoride, and calcium hypochlorite.

Division 5.2 (organic peroxide) consists of any organic compound containing oxygen (O) in the bivalent -O-O- structure that can be considered a derivative of hydrogen peroxide, where one or more of the hydrogen atoms have been replaced by organic radicals.

Division 5.2 (organic peroxide) materials are assigned to one of seven types:

Type A - organic peroxide that can detonate or deflagrate rapidly as packaged for transport. Transportation of Type A organic peroxides is forbidden.

Type B - organic peroxide that neither detonates nor deflagrates rapidly, but that can undergo a thermal explosion.

Type C - organic peroxide that neither detonates nor deflagrates rapidly and cannot undergo a thermal explosion.

Type D - organic peroxide that detonates only partially or deflagrates slowly, with medium to no effect when heated under confinement.

Type E - organic peroxide that neither detonates nor deflagrates and shows low, or no, effect when heated under confinement.

Type F - organic peroxide that will not detonate, does not deflagrate, shows only a low, or no, effect if heated when confined, and has low, or no, explosive power.

Type G - organic peroxide that will not detonate, does not deflagrate, shows no effect if heated when confined, and has no explosive power, is thermally stable, and is desensitized.

Examples of Division 5.2 materials include dibenzoyl peroxide, methyl ethyl ketone peroxide, and peroxyacetic acid.

Class 6 (Poisonous Materials)

Division 6.1 (poisonous material) consists of materials, other than gases, that either are known to be so toxic to humans as to afford a hazard to health during transportation, or in the absence of adequate data on human toxicity, are presumed to be toxic to humans, including materials that cause irritation.

Examples of Division 6.1 materials include aniline, arsenic compounds, carbon tetrachloride, hydrocyanic acid, and tear gas.

Division 6.2 (infectious substance) consists of viable microorganisms, or their toxin, that cause or can cause disease in humans or animals. Infectious substance and etiologic agent are synonymous.

Examples of Division 6.2 materials include anthrax, botulism, rabies, and tetanus.

Hazard zones associated with Class 6 materials are the following:

(a) Hazard zone A- LC_{50} less than or equal to 200 ppm

(b) Hazard zone B- LC_{50} greater than 200 ppm and less than or equal to 1,000 ppm

Class 7 (Radioactive Materials)

Radioactive material is any material having a specific activity greater than 0.002 microcuries per gram (mCi/g).

Examples of Class 7 materials include cobalt, uranium hexafluoride, and "yellow cake."

Class 8 (Corrosive Materials)

Corrosive material is a liquid or solid that causes visible destruction or irreversible alterations in human skin tissue at the site of contact or a liquid that has a severe corrosion rate on steel or aluminum.

Examples of Class 8 materials include nitric acid, phosphorus trichloride, sodium hydroxide, and sulfuric acid.

Class 9 (Miscellaneous Hazardous Materials)

Miscellaneous hazardous material is a material that presents a hazard during transport, but that is not included in another hazard class, including the following:

(a) Any material that has an anesthetic, noxious, or other similar property that could cause extreme annoyance or discomfort to a flight crew member so as to prevent the correct performance of assigned duties

(b) Any material that is not included in any other hazard class, but is subject to the DOT requirements (a hazardous substance or a hazardous waste)

Examples of Class 9 materials include adipic acid, hazardous substances (e.g., PCBs), and molten sulfur.

ORM-D Material

An ORM-D material is a material that presents a limited hazard during transportation due to its form, quantity, and packaging.

Examples of ORM-D materials include consumer commodities and small arms ammunition.

Forbidden

Forbidden means prohibited from being offered or accepted for transportation. Prohibition does not apply if these materials are diluted, stabilized, or incorporated in devices.

Marine Pollutant

A marine pollutant is a material that has an adverse effect on aquatic life.

Elevated Temperature Material

An elevated temperature material is a material that, when offered for transportation in a bulk packaging, meets one of the following conditions:

(a) Liquid at or above 100ºC (212ºF)

(b) Liquid with a flash point at or above 37.8ºC (100ºF) that is intentionally heated and is transported at or above its flash point

(c) Solid at a temperature at or above 240ºC (464ºF)

A-2-2.1.11 These clues would include odors, gas leaks, fire or vapor cloud, visible corrosive actions or chemical reactions, pooled liquids, hissing of pressure releases, condensation lines on pressure tanks, injured victims, or casualties.

A-2-2.3 It is the intent of this standard that the first responder at the awareness level be taught the noted competency to a specific task level. This task level would be to have knowledge of the contents of the current edition of the *North American Emergency Response Guidebook* or other reference material provided. Awareness level responders should be familiar with the information provided in those documents so that they can use it to assist with accurate notification of an incident and take protective actions.

If other sources of response information [including the material safety data sheet (MSDS)] are provided to the hazardous materials responder at the awareness level in lieu of the current edition of the *North American Emergency Response Guidebook*, the responder should identify hazard information similar to that found in the current edition of the *North American Emergency Response Guidebook*.

A-2-2.3.1 Three methods for determining the appropriate guide page include the following:

(a) Using the numerical index for UN/NA identification numbers

(b) Using the alphabetical index for chemical names

(c) Using the "Table of Placards and Initial Response Guides"

A-2-4.1 Those jurisdictions that have not developed an emergency response plan can refer to the document NRT-1, *Hazardous Materials Emergency Planning Guide*, developed by the National Response Team.

The National Response Team, composed of 14 federal agencies having major responsibilities in environmental, transportation, emergency management, worker safety, and public health areas, is the national body responsible for coordinating federal planning, preparedness, and response actions related to oil discharges and hazardous substance releases. Under the Superfund Amendments and Reauthorization Act of 1986, the NRT is responsible for publishing guidance documents for the preparation and implementation of hazardous substance emergency plans.

A-2-4.1.3.3 This would include thermal, mechanical, poisonous, corrosive, asphyxiation, radiation, and etiologic. This can also include psychological harm.

A-2-4.1.3.4 General routes of human exposure are contact, absorption, inhalation, and ingestion. Absorption includes entry through the eyes and through punctures.

A-2-4.1.4 If other sources of response information [including the material safety data sheet (MSDS)] are provided to the hazardous materials responder at the awareness level in lieu of the current edition of the *North American Emergency Response Guidebook*, the responder should identify response information similar to that found in the current edition of the *North American Emergency Response Guidebook*.

A-2-4.1.4.2(c) "In-place protection," "sheltering in-place," and "protection in-place" all mean the same thing.

A-3-2.1 The survey of the incident should include an inventory of the type of containers involved, identification markings on containers, quantity in or capacity of containers, materials involved, release information, and surrounding conditions. The accuracy of the data should be verified.

A-3-2.1.1 Examples should include all containers, including nonbulk packaging, bulk packaging, vessels, and facility containers such as piping, open piles, reactors, and storage bins. Refer to the Chemical Manufacturers Association/Association of American Railroads Hazardous Materials Technical Bulletin *Packaging for Transporting Hazardous and Non-hazardous Materials*, issued June 1989.

A-3-2.1.4 The list of surrounding conditions should include: topography; land use; accessibility;

weather conditions; bodies of water; public exposure potential; overhead and underground wires and pipelines; storm and sewer drains; possible ignition sources; adjacent land use such as rail lines, highways, and airports; and nature and extent of injuries. Building information such as floor drains, ventilation ducts, air returns, etc., also should be included when appropriate.

A-3-2.3 Predicting the likely behavior of a hazardous material and its container requires the ability to identify the types of stress involved and the ability to predict the type of breach, release, dispersion pattern, length of contact, and the health and physical hazards associated with the material and its container. Reference can be made to *A Textbook for Use in the Study of Hazardous Materials Emergencies,* the National Fire Academy's training program, *Hazardous Materials Incident Analysis, Hazardous Materials*; *Managing the Incident*, or "Managing the Hazardous Materials Incident," *Fire Protection Handbook*.

A-3-2.3.2 The three types of stress that could cause a container to release its contents are thermal stress, mechanical stress, and chemical stress.

A-3-2.3.3 The five ways in which containers can breach are disintegration, runaway cracking, closures opening up, punctures, and splits or tears.

The performance objectives contained in 3-2.3.3 through 3-2.3.5 should be taught in a manner and language understandable to the audience. The intent is to convey the simple concepts that containers of hazardous materials under stress can open up and allow the contents to escape. This refers to both pressurized and nonpressurized containers. This content release will vary in type and speed. A pattern will be formed by the escaping product that will possibly expose people, the environment, or property, creating physical and/or health hazards. This overall concept is often referred to as a general behavior model and is used to estimate the behavior of the container and its contents under emergency conditions.

A-3-2.3.4 The four ways in which containment systems can release their contents are detonation, violent rupture, rapid relief, and spill or leak.

A-3-2.3.5 The seven dispersion patterns that can be created upon release of hazardous materials are hemisphere, cloud, plume, cone, stream, pool, and irregular.

A-3-2.3.6 The three general time frames for predicting the length of time that an exposure can be in contact with hazardous materials in an endangered area are short-term (minutes and hours), medium-term (days, weeks, and months), and long-term (years and generations).

A-3-2.3.7 The health and physical hazards that could cause harm in a hazardous materials incident are thermal, mechanical, poisonous, corrosive, asphyxiation, radiation, and etiologic.

A-3-2.3.8 Health Hazard Definitions.
(a) *Carcinogen:* A chemical that falls within any of the following categories:

1. It has been evaluated by the International Agency for Research on Cancer (IARC) and found to be a carcinogen or potential carcinogen

2. It is listed as a carcinogen or potential carcinogen in the *Annual Report on Carcinogens* published by the National Toxicology Program (NTP) (latest edition)

3. It is regulated by federal OSHA as a carcinogen (can be regulated additionally by states)

(b) *Corrosive:* A chemical that causes visible destruction of, or irreversible alterations in, living tissue by chemical action at the site of contact

(c) *Highly toxic:* A chemical that falls within any of the following categories:

1. A chemical that has a median lethal dose (LD_{50}) of 50 mg or less per kg of body weight when administered orally to albino rats weighing between 200 g and 300 g each

2. A chemical that has a median lethal dose (LD_{50}) of 200 mg or less per kg of body weight when administered by continuous contact for 24 hours (or less if death occurs within 24 hours) with the bare skin of albino rabbits weighing between 2 kg and 3 kg each

3. A chemical that has a median lethal concentration (LD_{50}) in air of 200 parts per million by volume or less of gas or vapor, or 2 mg per L or less of mist, fume, or dust, when administered by continuous inhalation for 1 hour (or less if death occurs within 1 hour) to albino rats weighing between 200 g and 300 g each

(d) *Irritant:* A chemical that is not corrosive but that causes a reversible inflammatory effect on living tissue by chemical action at the site of contact

(e) *Sensitizer:* A chemical that causes a substantial proportion of exposed people or animals to develop an allergic reaction in normal tissue after repeated exposure to the chemicals

(f) *Toxic:* A chemical that falls within any of the following categories:

1. A chemical that has a median lethal dose (LD_{50}) or more than 50 mg per kg but not more than 500 mg per kg of body weight when administered orally to albino rats weighing between 200 g and 300 g each

2. A chemical that has a median lethal dose (LD_{50}) of more than 200 mg per kg but not more than 1,000 mg per kg of body weight when administered by continuous contact for 24 hours (or less if death occurs within 24 hours) with the bare skin of albino rabbits weighing between 2 kg and 3 kg each

3. A chemical that has a median lethal concentration (LD_{50}) in air of more than 200 parts per million but not more than 3,000 parts per million by volume of gas or vapor, or more than 2 mg per L but not more than 200 mg per L of mist, fume, or dust, when administered by continuous inhalation for 1 hour (or less if death occurs within 1 hour) to albino rats weighing between 200 g and 300 g each

(g) *Target organ effects:* A target organ categorization of effects that can occur, including examples of signs and symptoms and chemicals that have been found to cause such effects. These examples are presented to illustrate the range and diversity of effects and hazards that can be encountered and is not intended to be all-inclusive.

1. *Hepatotoxins*. Chemicals that produce liver damage (signs and symptoms: jaundice, liver enlargement; chemicals: carbontetrachloride, nitrosamines)

2. *Nephrotoxins*. Chemicals that produce kidney damage (signs and symptoms: edema, protein urea; chemicals: halogenated hydrocarbons, uranium)

3. *Neurotoxins*. Chemicals that produce their primary toxic effects on the nervous system
a. *Central Nervous System Hazards:* Chemicals that cause depression or stimulation of consciousness or otherwise injure the brain

b. *Peripheral Nervous System Hazards:* Chemicals that damage the nerves that transmit messages to and from the brain and the rest of the body (signs and symptoms: numbness, tingling, decreased sensation, change in reflexes, decreased motor strength; examples: arsenic, lead, toluene, styrene)

4. Agents that decrease hemoglobin in the blood of function; deprive the hematopolatic body tissues of oxygen system (signs and symptoms: cyanosis, loss of consciousness; chemicals: carbon monoxide, benzene)

5. Agents that irritate the lung or damage the pulmonary tissue (signs and symptoms: cough, tightness in chest, shortness of breath; chemicals: silica, asbestos, HCL)

6. *Reproductive toxins*. Chemicals that affect the reproductive capabilities, including chromosomal damage (mutations) and effects on fetuses (teratogenesis) (signs and symptoms: birth defects, sterility; chemicals: lead, DBCP)

7. *Cutaneous hazards*. Chemicals that affect the dermal layer of the body (signs and symptoms: defatting of the skin, rashes, irritation; chemicals: ketones, chlorinated compounds)

8. *Eye hazards*. Chemicals that affect the eye or visual capacity (signs and symptoms: conjunctivitis, corneal damage; chemicals: organic solvents, acids)

A-3-2.3.8(b) Chronic health hazards include carcinogen, mutagen, and teratogen.

A-3-2.4 The process for estimating the potential outcomes within an endangered area at a hazardous materials incident includes determining the dimensions of the endangered area, estimating the number of exposures within the endangered area, measuring or predicting concentrations of materials within the endangered area, estimating the physical, health, and safety hazards within the endangered area, identifying the areas of potential harm within the endangered area, and estimating the potential outcomes within the endangered area.

A-3-2.4.1 Resources for determining the size of an endangered area of a hazardous materials incident is the current edition of the *North American Emergency Response Guidebook* and plume dispersion modeling results from facility pre-incident plans.

A-3-2.4.4 The factors for determining the extent of physical, health, and safety hazards within an endangered area at a hazardous materials incident are surrounding conditions, an indication of the behavior of the hazardous material and its container, and the degree of hazard.

A-3-3.3.1 The minimum requirement for respiratory protection at hazardous materials incidents (emergency operations until concentrations have been determined) is positive pressure self-contained breathing apparatus. Therefore, the minimum for the first responder at the operational level is positive pressure self-contained breathing apparatus.

A-3-3.4, A-3-4.1.5 Refer to *Hazardous Materials Response Handbook*, National Fire Protection Association, Quincy, MA.

A-3-4.1.6 Refer to NIOSH/OSHA/USCG/EPA *Occupational Safety and Health Guidance*

Manual for Hazardous Waste Site Activities.

A-3-4.2 See A-2-4.1.

A-3-4.2.6 The hazardous materials safety officer should meet all the competencies for the responder at the level of operations being performed.

A hazardous materials branch safety officer is an individual who directs the safety of operations within the hot and warm zones. A hazardous materials branch safety officer should be designated specifically at all hazardous material incidents (CFR 1910.120). The hazardous materials safety officer has the following responsibilities:

(a) Obtains a briefing from the incident commander or incident safety officer and the hazardous materials branch safety officer

(b) Participates in the preparation of and monitors the implementation of the incident safety considerations (including medical monitoring of entry team personnel before and after entry)

(c) Advises the incident commander/sector officer of deviations from the incident safety considerations and of any dangerous situations

(d) Alters, suspends, or terminates any activity that is judged to be unsafe

A-4-1.3 The following site safety plan considerations are referenced from the *Standard Operating Safety Guides,* EPA, June 1992:

(a) Site description

(b) Entry objectives

(c) On-site organization

(d) On-site control

(e) Hazard evaluation

(f) Personal protective equipment

(g) On-site work plans

(h) Communication procedures

(i) Decontamination procedures

(j) Site safety and health plan.

A-4-2.1.3 Suggested materials to identify can include the most commonly released materials that are identified on several lists annually (EPA, State of California).

A-4-2.1.3.4 These factors include, but are not limited to, operation, calibration, response time, detection range, relative response, sensitivity, selectivity, inherent safety, environmental conditions, and nature of hazard. Also refer to NIOSH/OSHA/USCG/EPA *Occupational Safety and Health Guidance Manual for Hazardous Waste Site Activities,* October 1985.

A-4-2.1.3.5 For example, the techniques for the use of the monitoring equipment should include monitoring for lighter than air gases in a confined area, heavier than air gases and vapors in a confined area, and heavier than air gases and vapors in an unconfined area.

A-4-2.2.1 For example, the significance of high concentrations of three airborne hazardous materials readings at scenarios relative to the hazards and harmful effects of the hazardous materials on the responders and the general public should be known.

A-4-2.2.4 The selection of scenarios to test the knowledge and ability to identify exposure symptoms should consider the following:

(a) Select materials common to the jurisdiction. This selection can be based on historical local records or any of the lists of materials that are commonly spilled throughout the country (i.e., chlorine, anhydrous ammonia, mineral acids, bases, aliphatic and aromatic solvents).

(b) Select concentrations and formulation of the materials common to the jurisdiction. It is especially important with pesticides to select realistic scenarios since the state of matter, behavior, and exposure routes can vary considerably from technical-grade materials to common-use formulations.

(c) Select weather conditions and release conditions appropriate to the jurisdiction since the behavior and the exposure hazards can vary considerably from summer conditions in the deep south to winter conditions in the north.

A-4-2.3 The condition of the container should be described using one of the following terms:

(a) Undamaged, no product release

(b) Damaged, no product release

(c) Damaged, product release

(d) Undamaged, product release

A-4-2.3.1 See Appendix D for the appropriate reference guides.

A-4-2.3.4 Some of the types of damage that containers can incur include the following:
(a) *Cracks.* A crack is a narrow split or break in the container metal that can penetrate through the metal of the container.

(b) *Scores.* A score is a reduction in the thickness of the container shell. It is an indentation in the container made by a relatively blunt object. A score is characterized by the relocation of the container or weld metal in such a way that the metal is pushed aside along the track of contact with the blunt object.

(c) *Gouges.* A gouge is a reduction in the thickness of the container. It is an indentation in the shell made by a sharp, chisel-like object. A gouge is characterized by the cutting and complete removal of the container or weld metal along the track of contact.

(d) *Dents.* A dent is a deformation of the container metal. It is caused by impact with a relatively blunt object. With a sharp radius, there is the possibility of cracking.

A-4-2.5.2.2

(a) Types:

1. Alpha

2. Beta

3. Gamma

(b) Units of measurement:

1. Activity

2. Quantity gamma

3. Absorbed dose

(c) Protection factors:

1. Half-life

2. Inverse square law

3. Time, distance, and shielding

The radiation absorbed dose (rad) and the roentgen equivalent man (rem) were used for many years to measure the amount and effect of ionizing radiation absorbed by humans. While officially replaced by the gray and the sievert, both rad and rem are still used. The rad equals the energy absorption of 100 ergs per gram of irradiated material (an erg is a unit of work or energy). The rem is the absorbed dose of ionizing radiation that produces the same biological effect as 1 rad of X rays or gamma rays (which are equal). The rem of X rays and gamma rays is therefore equal to the rad; for each type of radiation the number of rads is multiplied by a specific factor to find the number of rems. The millirem, 0.001 rems, is also frequently used; the average radiation dose received by a person in the United States is about 180 millirems per year.

In the SI system (Systeme International d' Unite's, or International System of Units), the gray and the sievert are used to measure radiation absorbed; these units have largely superseded the older rad and rem. The gray (Gy), equal to 100 rads, is now the base unit. It is also expressed as the energy absorption of 1 joule per kilogram of irradiated material. The sievert (Sv) is the absorbed dose of radiation that produces the same biological effect as 1 gray of X rays or gamma rays. The sievert is equal to 100 rems, and has superseded the rem. The becquerel (Bq) measures the radioactive strength of a source, but does not consider effects on tissue. One becquerel is defined as one disintegration (or other nuclear transformation) per second.

Curie

A curie is the standard unit of radioactivity, being the quantity of a radioactive isotope that decays at a rate of 3.7×10^{10} disintegrations per second.

Roentgen

A roentgen is the international unit of the intensity of X rays or gamma rays. It is the quantity of radiation that would produce, in air, ions carrying a positive or negative charge equal to one electrostatic unit in 0.001293 grams of air.

A-4-2.5.3 See A-3-2.4.

A-4-3.3.3.3 Refer to the Chemical Manufacturers Association and Association of American Railroads Hazardous Materials Technical Bulletin *Recommended Terms for Personal Protective Equipment*, issued October 1985. Also refer to NFPA 1991, *Standard on Vapor-Protective Suits for Hazardous Chemical Emergencies;* NFPA 1992, *Standard on Liquid Splash-Protective Suits for Hazardous Chemical Emergencies;* and NFPA 1993, *Standard on Support Function*

Protective Clothing for Hazardous Chemical Operations.

A-4-3.5.4 Safety hazards associated with confined spaces could include the following:

(a) Atmospheric hazards, such as the following:

1. Oxygen-deficient atmosphere
2. Oxygen-enriched atmosphere
3. Flammable/explosive atmosphere
4. Toxic atmosphere

(b) Physical hazards, such as the following:

1. Engulfment hazards
2. Falls/slips
3. Electrical hazards
4. Structural hazards
5. Mechanical hazards

A-4-4.2.2 Emergency procedures for personnel wearing vapor-protective clothing should include procedures for the following:

(a) Loss of air supply

(b) Loss of suit integrity

(c) Loss of verbal communications

(d) Buddy down in hot zone

A-4-4.2.3 Competency for wearing positive pressure self-contained breathing apparatus should have been met as part of Chapter 3.

A-4-4.3.1, A-4-4.3.2 Contact the Chlorine Institute for assistance in obtaining training on the use of the various chlorine kits.

A-4-4.3.7 The safety considerations for product transfer operations should include the following:

(a) Bonding

(b) Grounding

(c) Elimination of ignition sources and shock hazards

A-4.4.3.11 Product removal and transfer considerations should include the following:
(a) Inherent risks associated with such operations

(b) Procedures and safety precautions

(c) Equipment required

A-5-1.3 The following site safety plan considerations are referenced from the *Standard Operating Safety Guides*, EPA, June 1992:

(a) Site description

(b) Entry objectives

(c) On-site organization

(d) On-site control

(e) Hazard evaluation

(f) Personal protective equipment

(g) On-site work plans

(h) Communication procedures

(i) Decontamination procedures

(j) Site safety and health plan

A-5-2.2.3
(a) Types:

1. Alpha

2. Beta

3. Gamma

(b) Units of measurement:

1. Activity

2. Quantity gamma

3. Absorbed dose

(c) Protection factors:

1. Half-life

2. Inverse square law

3. Time, distance, and shielding

A-5-3.4.5.3 Safety precautions should include the following:

(a) Buddy systems

(b) Backup team

(c) Personal protective equipment

A-5-3.4.5.5 See A-4-3.5.4.

A-5-4.2 Criteria/factors should include the following:

(a) Task assignment (based upon strategical and tactical options)

(b) Operational safety

(c) Operational effectiveness

(d) Planning support

(e) Logistical support

(f) Administrative support

A-5-6.1.1 The appropriate steps to transfer command/control of the incident include the following:

(a) Fully brief the incoming command/control person on the details of the incident

(b) Communicate the transfer of command/control to all other interests involved in the incident

A-6-3.1.2 An example of a private sector specialist employee B is a person who regularly loads and unloads tank trucks of the specific chemical involved in the incident as part of their regular job. At a hazardous materials incident, this person would be assigned the task of transferring the contents of the damaged tank truck into another container. The private sector specialist employee B would not be involved with chemicals for which the responder has not been trained. This person would leave the hot or warm zone when this work is completed.

A-6-3.1.3 The following site safety plan considerations are referenced from the *Standard Operating Safety Guides*, EPA, June 1992:

(a) Site description

(b) Entry objectives

(c) On-site organization

(d) On-site control

(e) Hazard evaluation

(f) Personal protective equipment

(g) On-site work plans

(h) Communication procedures

(i) Decontamination procedures

(j) Site safety and health plan

A-6-3.4.1.2 Such factors include heat, cold, working in confined space, working in personal protective equipment, working in a flammable or toxic atmosphere, and pre-existing health conditions.

A-7-4.2 These abilities should include the following:

(a) Task assignment (based upon strategical and tactical options)

(b) Operational safety

(c) Operational effectiveness

(d) Planning support

(e) Information/research

(f) Logistical support

(g) Administrative support

A-8-1.1 These competencies are intended to address even situations when no "hazardous materials branch" is established, such as when only defensive (operational level) activities are being conducted.

If only defensive activities (i.e., at the operational level) are being conducted, the hazardous materials branch safety officer shall be trained to at least the operational level and in addition shall meet the competencies of this chapter.

If the functions and responsibilities of the hazardous materials branch safety officer are performed by the overall incident safety official or on-scene incident commander, that individual shall meet the competencies of this chapter.

A-8-1.2 Under this section, the hazardous materials branch safety officer is given specific responsibilities. It should be understood that even though these duties are to be carried out by the hazardous materials branch safety officer, the incident commander still has overall responsibility for the implementation of these tasks.

A-8-2.1.1 See A-4-2.5.2.2.

A-8-2.1.4 Conditions where protective clothing with thermal protection might be required if entry was made into an area where flammability was a concern can include the following:

(a) Unknown materials involved

(b) Oxygen-enriched atmosphere

(c) Detectable percent of LEL on monitoring instruments

(d) Materials with a wide flammable range present

(e) Reactive materials present

A-8-2.1.5 Conditions under which personnel would not be allowed in the hot zone include the following:

(a) Decontamination procedures not established or in place

(b) Advanced first aid and transportation not available

(c) Flammable atmosphere present

(d) Oxygen-enriched atmosphere of 23.5 percent or greater present

(e) Runaway reaction occurring

(f) Appropriate personal protective clothing not available

(g) No effective action can be taken

(h) Risk outweighs benefit

(i) Personnel not properly trained

(j) Insufficient personnel to perform tasks

A-8-2.1.8 Examples of scenarios that would help prepare emergency responders for situations they might encounter in the field include the following:

(a) Ammonia leaking from a fitting or valve of a railroad tank car

(b) Chlorine leaking from the valve stem of a 150-lb (68-kg) cylinder

(c) Lacquer thinner leaking from a hole in a 55-gal (208-L) drum

(d) Gasoline leaking from a hole in the side of an aluminum tank truck

(e) Carbaryl, a powdered insecticide, found stored in a broken cardboard drum

A-8-2.1.9.4 Such limiting factors include, but are not limited to, operation, calibration, response time, detection range, relative response, sensitivity, selectivity, inherent safety, environmental conditions, and nature of hazard. Also refer to *Standard Operating Safety Guides*, EPA, June 1992.

A-8-3.1 Potential action options are either defensive or offensive in nature. See NFPA 471, *Recommended Practice for Responding to Hazardous Materials Incidents.*

A-8-3.1.1 Safety precautions to observe while mitigating hazards or conditions can include the following:

(a) Elimination of ignition sources

(b) Using monitoring instruments

(c) Stabilizing the container

(d) Establishing emergency evacuation procedures

(e) Ensuring availability of hose lines and foam, when appropriate

(f) Evacuating exposures

(g) Isolating the area

(h) Protecting in place

(i) Wearing proper protective equipment

A-8-3.1.2 Safety precautions to be observed during search and rescue missions at hazardous materials incidents can include the following:

(a) Ensuring availability of appropriate personal protective clothing for all personnel

(b) Using monitoring instruments

(c) Maintaining an escape path

(d) Knowledge of approved hand signals by all personnel

(e) Ensuring availability of communications equipment for each team

(f) Preplanning the search sequence prior to entry

A-8-3.3.1 Benefits of pre-emergency planning include the following:

(a) Identifies and mitigates hazards during the planning process

(b) Familiarizes personnel with facility

(c) Identifies 24-hour responsible parties

(d) Identifies built-in containment systems

(e) Identifies the location of utility and other shutoff/shutdown valves and switches

(f) Identifies location of facility map

(g) Identifies location and quantities of hazardous materials

(h) Identifies vulnerable populations

(i) Identifies facility response capabilities

A-8-3.3.2 Hazards to observe when approaching a hazardous materials incident include the following:

(a) Inhalation hazard

(b) Dermal hazard

(c) Flammable hazard

(d) Reactive hazard

(e) Electrical hazard

(f) Mechanical hazard

A-8-3.3.3 The following are the elements of a site safety plan referenced from the *Standard Operating Safety Guides*, EPA, June 1992:

(a) Site description

(b) Entry objectives

(c) On-site organization

(d) On-site control

(e) Hazard evaluation

(f) Personal protective equipment

(g) On-site work plans

(h) Communication procedures

(i) Decontamination procedures

(j) Site safety and health plan

A-8-3.5.4 Typical action options can include surveying the scene, sampling, monitoring, plugging, and patching.

A-8-3.7.1 The elements of an emergency medical services plan according to NFPA 473, *Standard for Competencies for EMS Personnel Responding to Hazardous Materials Incidents,* include the following:

(a) EMS control activities

(b) EMS component of an incident management system

(c) Medical monitoring of personnel utilizing chemical-protective and high temperature-protective clothing

(d) Triage of hazardous materials victims

(e) Medical treatment for chemically contaminated individuals

(f) Product and exposure information gathering and documentation

A-8-4.4.9 Safety considerations that can minimize secondary contamination include the following:

(a) Control zones are established and enforced

(b) All people and equipment exiting the hot zone are decontaminated

(c) Personnel performing decontamination are properly trained

(d) Personnel performing decontamination are properly protected

See NFPA 473, *Standard for Competencies for EMS Personnel Responding to Hazardous Materials Incidents*.

A-8-4.5.1 Communications systems include in-suit radio communications, hand-held portable radios, air horns, and hand signals.

A-8-5.2.1.1 Examples of such situations or conditions can include, but are not limited to, the following:

(a) Fire or explosion

(b) Container failure

(c) Sudden change in weather conditions

(d) Failure of entry team personal protective clothing and/or equipment

(e) Updated information on identification of hazardous materials(s) involved warranting reassessment of level of protective clothing and equipment being used

A-8-6.2.1 Topics can include, but are not limited to, the following:

(a) The identity of the hazardous materials to which personnel have been or may have been exposed

(b) The signs and symptoms of exposure to the hazardous material(s) involved in the incident

(c) The signs and symptoms of critical incident stress

(d) The duration of a recommended observation period for such signs and symptoms

(e) Procedures to follow in the event of delayed presentation of such signs or symptoms

(f) The name of the individual responsible for post-incident medical contact

(g) Safety and health hazards remaining at the site

A-9-2.1.11 The heat-affected zone is an area in the metal next to the actual weld. This zone is less ductile than either the weld or the metal due to the effect of the welding process. The heat-affected zone is vulnerable to cracks.

A-9-2.1.16 Other methods for determining the amount of liquid include shipping papers, the presence of frost line, the use of touch to feel for the colder liquid level, and the use of heat sensors..

A-9-4.1.9 When bonding and grounding, a ground resistance tester and an ohm meter should be used. The ground resistance tester measures the earth's resistance to a ground rod, and the ohm meter measures the resistance of the connections to ensure electrical continuity. One ground rod might not be enough; more may have to be driven and connected to the first to ensure a good ground. Resistance varies with types of soils.

A-10-2.1.5 See A-9-2.1.16.

A-10-4.1.3 See A-9-4.1.9.

A-11-2.1.9 Methods for determining the amount of liquid include the use of gauges, shipping papers, the presence of frost line, the use of touch or feel for the colder liquid level, and the use of heat sensors.

A-11-2.1.10 See A-9-2.1.11.

A-11-4.1.3, A-11-4.1.7, A-11-4.1.8, A-11-4.1.9 See A-9-4.1.9.

Appendix B Competencies for the Technician with a Flammable Liquids Bulk Storage Specialty

This appendix is not a part of the requirements of this NFPA document but is included for informational purposes only.

B-1 General.

B-1.1 Introduction. Technicians with a flammable liquids bulk storage specialty should meet all requirements of the first responder awareness, operational, and hazardous materials technician levels and the competencies of this Appendix. The technician with a flammable liquids bulk storage specialty also should receive additional training to meet applicable United States Environmental Protection Agency (EPA), Occupational Safety and Health Administration (OSHA), and other appropriate state, local, or provincial occupational health and safety regulatory requirements.

B-1.2 Definition. Technicians with a flammable liquids bulk storage specialty are those persons who, in incidents involving bulk flammable liquid storage tanks, provide support to the hazardous materials technician and other personnel, provide strategical and tactical recommendations to the on-scene incident commander, provide oversight for fire control and product removal operations, and act as a liaison between technicians, fire fighting personnel, and other outside resources. These technicians are expected to use appropriate personal protective clothing and specialized fire, leak, and spill control equipment.

B-1.3 Goal. The goal of this Appendix is to provide the technicians with a flammable liquids bulk storage specialty with the knowledge and skills to perform the following tasks safely. In addition to being competent at the technician levels, the technician with a flammable liquids bulk storage specialty should be able to:

(a) Analyze an incident involving a bulk flammable liquid storage tank to determine the magnitude of the problem by completing the following tasks:

1. Determine the type and extent of damage to the bulk liquid storage tank

2. Predict the likely behavior of the bulk liquid storage tank and its contents in an incident

(b) Plan a response for an incident involving a flammable liquid bulk storage tank within the capabilities and competencies of available personnel, personal protective equipment, and control equipment by completing the following tasks:

1. Determine the response options (offensive, defensive, and nonintervention) for a hazardous materials incident involving flammable liquid bulk storage tanks

2. Ensure that the options are within the capabilities and competencies of available personnel, personal protective equipment, and control equipment

(c) Implement the planned response to a hazardous materials incident involving a flammable liquid bulk storage tank

B-1.4 Mandating of Competencies. This standard does not mandate that hazardous materials response teams performing offensive operations on flammable liquids bulk storage tanks have technicians with a flammable liquids bulk storage specialty. Technicians operating within the bounds of their training as listed in Chapter 4 of this standard are able to intervene in flammable liquids bulk storage incidents. However, if a hazardous materials response team desires to train some or all its technicians to have in-depth knowledge of flammable liquids bulk storage facilities, this Appendix sets out the recommended competencies.

B-2 Competencies - Analyzing the Incident.

B-2.1 Determining the Type and Extent of Damage to the Bulk Storage Tank. Given examples of storage tank incidents, technicians with a flammable liquids bulk storage specialty should describe the type of storage tank, and the type and extent of damage to the tank and its associated piping and fittings. The technician with a flammable liquids bulk storage specialty should be able to:

B-2.1.1 Given examples of various flammable liquid bulk storage operations, identify and describe the procedures for the normal movement and transfer of product(s) into and out of the facility and storage tanks.

Examples should be based upon local or regional facilities and could include marketing terminals, pipeline operations and terminals, refineries, and bulk storage facilities.

B-2.1.2 Given examples of the following atmospheric pressure bulk liquid storage tanks, describe the tank's design and construction features, and types of products commonly found.

(a) Cone roof tank

(b) Open (external) floating roof tank

(c) Open floating roof tank with a geodesic dome external roof

(d) Covered (internal) floating roof tank

According to NFPA 30, *Flammable and Combustible Liquids Code*, atmospheric tanks are defined as storage tanks operating at pressures from atmospheric to 0.5 psig. The floating roof on an open floating roof tank can be a pan roof or a pontoon floating roof, while the floating roof on a covered floating roof tank can be constructed of aluminum, steel or fiberglass, or a pontoon floating roof.

B-2.1.3 Given examples of the following types of low pressure horizontal and vertical bulk liquid storage tanks, describe the tank's uses and design and construction features.

(a) Horizontal tank

(b) Dome roof tank

According to NFPA 30, *Flammable and Combustible Liquids Code*, low pressure tanks are defined as storage tanks operating at pressures from 0.5 psig but not more than 15 psig.

B-2.1.4 Given examples of various atmospheric and low pressure bulk liquid storage tanks, describe the design and purpose of each of the following storage tank components, when present:

(a) Tank shell material of construction

(b) Type of roof and material of construction

(c) Primary and secondary roof seals (as applicable)

(d) Incident venting/pressure relief devices

(e) Tank valves

(f) Tank gauging devices

(g) Tank overfill device

(h) Secondary containment methods (as applicable)

(i) Tank piping and piping supports

(j) Fixed or semi-fixed fire protection system

B-2.1.5 Given three examples of primary and secondary spill confinement measures, describe the design, construction, and incident response considerations associated with each method provided.

B-2.2 Predicting the Likely Behavior of the Bulk Storage Tank and Contents. Technicians with a flammable liquids bulk storage specialty should predict the likely behavior of the tank and its contents. The technician with a flammable liquids bulk storage specialty should be able to:

B-2.2.1 Given examples of different types of bulk flammable liquid storage tank facilities, identify the impact of the following fire and safety features on the behavior of the products during an incident, when present:

(a) Tank spacing

(b) Product spillage and control (impoundment and diking)

(c) Tank venting and flaring systems

(d) Transfer and product movement capabilities

(e) Monitoring and detection systems

(f) Fire protection systems

B-2.2.2 Given a flammable liquid bulk storage tank involved in a fire, identify the factors to be evaluated as part of the risk assessment process, including the following:

(a) Type of storage tank

(b) Product involved

(c) Amount of product within the storage tank

(d) Nature of the incident (e.g., seal fire, tank overfill, full-surface fire, etc.)

(e) Tank spacing and exposures

(f) Fixed or semi-fixed fire protection systems present

B-2.2.3 Given three types of incidents involving flammable liquid bulk storage tanks, describe the likely fire and spill behavior for each incident.

Examples of fire and spill incidents could include tank overfills, seal fires on floating roof tanks, floating roof with a sunk internal roof, tank or piping failures, full surface fire, etc.

B-2.2.4 Describe the causes, hazards, and methods of handling the following conditions as they relate to fires involving flammable liquid bulk storage tanks:

(a) Frothover

(b) Slopover

(c) Boilover

For additional information, see NFPA 30, *Flammable and Combustible Liquids Code* and API 2021, *Guide for Fighting Fires In and Around Flammable and Combustible Atmospheric Petroleum Storage Tanks*.

B-3 Competencies - Planning the Response.

B-3.1 Determining the Response Options. Given an analysis of an incident involving flammable liquid storage tanks, technicians with a flammable liquids bulk storage specialty should determine response options for the storage tank involved. The technician with a flammable liquids bulk storage specialty should be able to:

B-3.1.1 Describe the factors to be evaluated in evaluating and selecting Class B fire fighting foam concentrates for use on flammable liquids.

B-3.1.2 Describe the factors to be considered for the portable application of Class B fire fighting foam concentrates for the following types of incidents:

(a) Flammable liquid spill (no fire)

(b) Flammable liquid spill (with fire)

(c) Flammable liquid storage tank fire

B-3.1.3 Given examples of different types of flammable liquid bulk storage tanks, identify and describe the application, use, and limitations of the types of fixed and semi-fixed fire protection systems that can be used, including the following:

(a) Foam chambers

(b) Catenary systems

(c) Subsurface injection system

(d) Fixed foam monitors

(e) Foam/water sprinkler systems

B-3.1.4 Describe the hazards, safety procedures, and tactical guidelines for handling an accumulated (in-depth) flammable liquid-spill fire.

B-3.1.5 Describe the hazards, safety procedures, and tactical guidelines for handling product/water drainage and runoff problems that can be created at a flammable liquid bulk storage tank fire.

B-3.1.6 Describe the hazards, safety procedures, and tactical guidelines for handling a flammable liquid bulk storage tank with a sunken floating roof.

B-3.1.7 Given a flammable liquid storage tank fire, describe the methods and associated safety considerations for extinguishing the following types of fires by using portable application devices:

(a) Pressure vent fire

(b) Seal fire on an open floating roof tank

(c) Seal fire on an internal floating roof tank

(d) Full-surface fire on an internal floating roof tank

(e) Full-surface fire on an external floating roof tank

(f) Dike fire

(g) Pipeline manifold fire

B-3.1.8 Given the size, dimensions, and products involved for a flammable liquid-spill fire, determine the following:

(a) Appropriate extinguishing agent

(b) Appropriate application method (both portable and fixed system application)

(c) Appropriate application rate and duration

(d) Required amount of Class B foam concentrate and required amount of water

(e) Volume and rate of application of water for cooling exposed tanks

For additional information, see NFPA 11, *Standard for Low-Expansion Foam*.

B-3.1.9 Given the size, dimensions, and product involved for a flammable liquid storage tank fire, determine the following:

(a) Appropriate extinguishing agent

(b) Appropriate application method (both portable and fixed system application)

(c) Appropriate application rate and duration

(d) Required amount of Class B foam concentrate and required amount of water

(e) Volume and rate of application of water for cooling involved and exposed tanks

For additional information, see NFPA 11, *Standard for Low-Expansion Foam*.

B-3.1.10 Given the size, dimensions, and product involved for a fire involving a single flammable liquid bulk storage tank and its dike area, determine the following:

(a) Appropriate extinguishing agent

(b) Appropriate application method (both portable and fixed system application)

(c) Appropriate application rate and duration

(d) Required amount of Class B foam concentrate and required amount of water

(e) Volume and rate of application of water for cooling involved and exposed tanks

For additional information, see NFPA 11, *Standard for Low-Expansion Foam*.

B-3.1.11 Given the size, dimensions, and product involved for multiple flammable liquid storage tanks burning within a common dike area, determine the following:

(a) Appropriate extinguishing agent

(b) Appropriate application method (both portable and fixed system application)

(c) Appropriate application rate and duration

(d) Amount of Class B foam concentrate and water required

(e) Volume and rate of application of water for cooling involved and exposed tanks

For additional information, see NFPA 11, *Standard for Low-Expansion Foam*.

B-4 Competencies - Implementing the Planned Response.

B-4.1 Implementing the Planned Response. Given an analysis of an incident involving flammable liquid storage tanks, technicians with a flammable liquids bulk storage specialty should implement or oversee the implementation of the selected response options safely and effectively. The technician with a flammable liquids bulk storage specialty should be able to:

B-4.1.1 Given a simulated flammable liquid fire, demonstrate the safe and effective methods for extinguishing the following types of fires by using portable application devices:

(a) Valve and/or flange fire

(b) Pump fire (horizontal or vertical)

(c) Pressure vent fire

(d) Large spill fire

(e) Storage tank fire

B-4.1.2 Given a simulated incident involving a three-dimensional flammable liquid fire, demonstrate the safe and effective method for controlling the fire by using portable application devices.

B-4.1.3 Demonstrate bonding and grounding procedures for the transfer of flammable liquids, including the following:

(a) Selection of proper equipment

(b) Sequence of bonding and grounding connections

(c) Proper testing of bonding and grounding connections

B-4.1.4 Given a simulated flammable liquid spill from a bulk storage tank or pipeline, describe the procedures for site safety and fire control during cleanup and removal operations.

Appendix C Competencies for the Technician with a Flammable Gases Bulk Storage Specialty

This appendix is not a part of the requirements of this NFPA document but is included for informational purposes only.

C-1 General.

C-1.1 Introduction. Technicians with a flammable gases bulk storage specialty should meet all requirements of the first responder awareness, operational, and hazardous materials technician levels and the competencies of this Appendix. The technician with a flammable gases bulk storage specialty also should receive additional training to meet applicable United States Environmental Protection Agency (EPA), Occupational Safety and Health Administration (OSHA), and other appropriate state, local, or provincial occupational health and safety regulatory requirements.

C-1.2 Definition. Technicians with a flammable gases bulk storage specialty are those persons who, in incidents involving bulk flammable gas storage tanks, provide support to the hazardous materials technician and other personnel, provide strategical and tactical recommendations to the on-scene incident commander, provide oversight for fire control and product removal operations, and act as a liaison between technicians, fire fighting personnel, and other outside resources. These technicians are expected to use appropriate personal protective clothing and specialized fire, leak, and spill control equipment.

C-1.3 Goal. The goal of this Appendix is to provide the technicians with a flammable gases bulk storage specialty with the knowledge and skills to perform the following tasks safely. In addition to being competent at the technician levels, the technician with a flammable gases bulk storage specialty should be able to:

(a) Analyze an incident involving a bulk flammable gas storage tank to determine the magnitude of the problem by completing the following tasks:

1. Determine the type and extent of damage to the bulk storage tank
2. Predict the likely behavior of the bulk storage tank and its contents in an incident

(b) Plan a response for an incident involving a flammable gas bulk storage tank within the capabilities and competencies of available personnel, personal protective equipment, and control equipment by completing the following tasks:

1. Determine the response options (offensive, defensive, and nonintervention) for a hazardous materials incident involving flammable gas bulk storage tanks

2. Ensure that the options are within the capabilities and competencies of available personnel, personal protective equipment, and control equipment

(c) Implement the planned response to a hazardous materials incident involving a flammable gas bulk storage tank

C-1-4 Mandating of Competencies. This standard does not mandate that hazardous materials response teams performing offensive operations on flammable gas bulk storage tanks have technicians with a flammable gases bulk storage specialty. Technicians operating within the bounds of their training as listed in Chapter 4 of this standard are able to intervene in flammable gas bulk storage incidents. However, if a hazardous materials response team desires to train some or all its technicians to have in-depth knowledge of flammable gas bulk storage facilities, this Appendix sets out the recommended competencies.

C-2 Competencies - Analyzing the Incident.

C-2.1 Determining the Type and Extent of Damage to the Bulk Storage Tank. Given examples of storage tank incidents, technicians with a flammable gases bulk storage specialty should describe the type of storage tank and extent of damage to the tank and its associated piping and fittings. The technician with a flammable gases bulk storage specialty should be able to:

C-2.1.1 Given examples of various flammable gas bulk storage operations, identify and describe the procedures for the normal movement and transfer of product(s) into and out of the facility storage tanks.

Examples should be based upon local or regional facilities and could include marketing terminals, pipeline operations and terminals, refineries, bulk storage facilities, and underground storage caverns.

C-2.1.2 Given examples of the following types of high pressure bulk gas storage tanks, describe the tank's uses and design and construction features.

(a) Horizontal (bullet) tank

(b) Spherical tank

Additional information on the design and construction of high pressure bulk gas storage tanks can be referenced from NFPA 58, *Standard for the Storage and Handling of Liquefied Petroleum Gases*, and API 2510-A, *Fire Protection Considerations for the Design and Operation of Liquefied Petroleum Gas (LPG) Storage Facilities*.

C-2.1.3 Given examples of various high pressure bulk gas storage tanks, point out and explain the design and purpose of each of the following storage tank components and fittings, when present:

(a) Liquid valve and vapor valve

(b) Safety relief valve

(c) Gauging device

(d) Tank piping and piping supports

(e) Fixed or semi-fixed fire protection system

C-2.2 Predicting the Likely Behavior of the Bulk Storage Tank and Contents. Technicians with a flammable gases bulk storage specialty should predict the likely behavior of the tank and its contents. The technician with a flammable gases bulk storage specialty should be able to:

C-2.2.1 Given examples of different types of bulk flammable gas storage tank facilities, identify the impact of the following fire and safety features on the behavior of the products during an incident, when present.

(a) Tank spacing

(b) Product spillage and control (impoundment and diking)

(c) Tank venting and flaring systems

(d) Transfer and product movement capabilities

(e) Monitoring and detection systems

(f) Fire protection systems

C-2.2.2 Given examples of different types of flammable gas bulk storage tanks, identify and describe the application, use, and limitations of the types of fixed and semi-fixed fire protection systems that can be used, including the following:

(a) Water spray systems

(b) Fixed foam monitors

(c) Fixed hydrocarbon monitoring systems

C-2.2.3 Given a flammable gas bulk storage tank and its associated piping, describe the likely breach/release mechanisms and fire scenarios.

C-3 Competencies - Planning the Response.

C-3.1 Determining the Response Options. Given an analysis of an emergency involving flammable gas storage tanks, technicians with a flammable gases bulk storage specialty should determine response options for the storage tank involved. The technician with a flammable gases bulk storage specialty should be able to:

C-3.1.1 Describe the hazards, safety, and tactical considerations required for the following types of flammable gas incidents:

(a) Flammable vapor release (no fire)

(b) Flammable vapor release (with fire)

(c) Liquefied flammable gas release (no fire)

(d) Liquefied flammable gas release (with fire)

C-3.1.2 Given a flammable gas storage tank with a liquid leak from the safety relief valve, describe the hazards, safety, and tactical considerations for controlling this type of leak.

C-3.1.3 Given a flammable gas fire from an elevated structure (e.g., tower or column), describe the hazards, safety, and tactical considerations for controlling this type of leak.

C-3.1.4 Describe the purpose of, potential risks associated with, procedures for, equipment required to implement, and safety precautions for the following product removal techniques:

(a) Transfer of liquids and vapors

(b) Flaring of liquids and vapors

(c) Venting

(d) Hot and cold tapping

C-3.1.5 Describe the effect flaring or venting of gas or liquid has on the pressure in the tank (flammable gas or flammable liquid product).

C-3.1.6 Describe the hazards, safety procedures, and tactical guidelines for handling product/water drainage and runoff problems that can be created at a flammable gas bulk storage facility incident.

C-4 Competencies - Implementing the Planned Response.

C-4.1 Implementing the Planned Response. Given an analysis of an emergency involving flammable gas bulk storage tanks, technicians with a flammable gases bulk storage specialty should implement or oversee the implementation of the selected response options safely and effectively. The technician with a flammable gases bulk storage specialty should be able to:

C-4.1.1 Given a simulated flammable gas incident, demonstrate the safe and effective method for controlling the following types of emergencies by using portable application devices:

(a) Unignited vapor release

(b) Valve and/or flange vapor release (no fire)

(c) Valve and/or flange fire

(d) Pump fire (horizontal or vertical)

C-4.1.2 Given a simulated incident involving the simultaneous release of both flammable liquids and flammable gases, demonstrate the safe and effective method for controlling the following types of emergencies by using portable application devices:

(a) Unignited vapor release

(b) Flange fire

(c) Pump seal fire

C-4.1.3 Demonstrate bonding and grounding procedures for the transfer of flammable gases, including the following:

(a) Selection of proper equipment

(b) Sequence of bonding and grounding connections

(c) Proper testing of bonding and grounding connections

C-4.1.4 Given a simulated flammable gas incident from a bulk storage tank or pipeline, describe the procedures for site safety and fire control during cleanup and removal operations.

Appendix D Referenced Publications

D-1 The following documents or portions thereof are referenced within this standard for informational purposes only and are thus not considered part of the requirements of this standard unless also listed in Chapter 12. The edition indicated here for each reference is the current edition as of the date of the NFPA issuance of this standard.

D-1.1 NFPA Publications. National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.

NFPA 11, *Standard for Low-Expansion Foam*, 1994 edition.

NFPA 30, *Flammable and Combustible Liquids Code*, 1996 edition.

NFPA 58, *Standard for the Storage and Handling of Liquefied Petroleum Gases*, 1995 edition.

NFPA 471, *Recommended Practice for Responding to Hazardous Materials Incidents*, 1997 edition.

NFPA 473, *Standard for Competencies for EMS Personnel Responding to Hazardous Materials Incidents*, 1997 edition.

NFPA 1561, *Standard on Fire Department Incident Management System*, 1995 edition.

NFPA 1991, *Standard on Vapor-Protective Suits for Hazardous Chemical Emergencies*, 1994 edition.

NFPA 1992, *Standard on Liquid Splash-Protective Suits for Hazardous Chemical Emergencies*, 1994 edition.

NFPA 1993, *Standard on Support Function Protective Clothing for Hazardous Chemical Operations*, 1994 edition.

Hazardous Materials Response Handbook.

D-1.2 Other Publications.

D-1.2.1 API Publications. American Petroleum Institute, 2101 L Street, NW, Washington, DC 20037.

API 2021, *Guide for Fighting Fires In and Around Flammable and Combustible Liquid Atmospheric Petroleum Storage Tanks*, 1991.

API 2510-A, *Fire Protection Considerations for the Design and Operation of Liquefied Petroleum Gas (LPG) Storage Facilities*, 1989.

D-1.2.2 Chemical Manufacturers Association Publications. Chemical Manufacturers

Association, 1300 Wilson Blvd., Arlington, VA 22209.

Packaging for Transporting Hazardous and Non-Hazardous Materials, June 1989 edition.

Recommended Terms for Personal Protective Equipment, 1985.

D-1.2.3 National Fire Academy Publication. National Fire Academy, Federal Emergency Management Agency, Emmitsburg, MD 21727.

Hazardous Materials Incident Analysis, 1984.

D-1.2.4 National Response Team Publication. National Response Team, National Oil and Hazardous Substances Contingency Plan, Washington, DC 20593.

NRT-1, *Hazardous Materials Emergency Planning Guide*, 1987.

D-1.2.5 U.S. Government Publications. U.S. Government Printing Office, Superintendent of Documents, Washington, DC 20402.

Title 29, *Code of Federal Regulations*, Parts 1910.119 - 1910.120

Title 40, *Code of Federal Regulations*, Part 261.33

Title 40, *Code of Federal Regulations*, Part 302

Title 40, *Code of Federal Regulations*, Part 355

Title 49, *Code of Federal Regulations*, Parts 170-179.

D-1.2.6 Miscellaneous Publications.

Benner, Ludwig, Jr., *A Textbook for Use in the Study of Hazardous Materials Emergencies*, 2nd edition, Lufred Industries, Inc., Oakton, VA, 1978.

Noll, Gregory G., et al., *Hazardous Materials, Managing the Incident*, 2nd edition, Fire Protection Publications, Stillwater, OK, 1995.

NIOSH/OSHA/USCG/EPA *Occupational Safety and Health Guidance Manual for Hazardous Waste Site Activities*, October 1985.

Wright, Charles J., "Managing the Hazardous Materials Incident," *Fire Protection Handbook*, 18th edition, National Fire Protection Association, Quincy, MA, 1997.

EPA, *Standard Operating Safety Guides*, June 1992.

Maslansky, Carol J. and Stephen P., "Air Monitoring Instrumentation", New York, NY, Van Nostrand Reinhold, 1993.

Grey, Gerald L., et al., *Hazardous Materials/Waste Handling for the Emergency Responder*, Fire Engineering Publications, New York, NY, 1989.

Standard for Competencies for EMS Personnel Responding to Hazardous Materials Incidents

1997 Edition

This edition of NFPA 473, *Standard for Competencies for EMS Personnel Responding to Hazardous Materials Incidents,* was prepared by the Technical Committee on Hazardous Materials Response Personnel and acted on by the National Fire Protection Association, Inc., at its Fall Meeting held November 18-20, 1996, in Nashville, TN. It was issued by the Standards Council on January 17, 1997, with an effective date of February 7, 1997, and supersedes all previous editions.

Changes other than editorial are indicated by a vertical rule in the margin of the pages on which they appear. These lines are included as an aid to the user in identifying changes from the previous edition.

This edition of NFPA 473 was approved as an American National Standard on February 7, 1997.

Origin and Development of NFPA 473

Following the development of NFPA 471 and NFPA 472, the Hazardous Materials Response Personnel Committee undertook the development of this standard relating to the professional competencies of emergency medical personnel who may be required to respond to hazardous materials incidents. The roles and responsibilities of EMS personnel at hazardous materials incidents had not been identified in the majority of emergency response systems. In this 1997 edition, the committee reviewed the document for consistency and clarity of the competencies.

Glenn P. Benarick, Fairfax County Fire & Rescue, VA [E]

Bud Berry, 3M, MN [M]
Rep. American Society of Safety Engr

Gene P. Carlson, Oklahoma State University, OK [U]
Rep. Int'l Fire Service Training Assn.

Don L. Crowson, Arlington Fire Dept., TX [U]

Thomas F. Dalton, Consulting Services Inc., NJ [U]
Rep. Spill Control Assn. of America

James L. Daneker, Los Angeles City Fire Dept., CA [C]

Jeffery C. Davis, Assn. of American Railroads, CO [RT.]

Manuel A. Ehrlich, Jr., BASF Corp., NJ [M]
Rep. Chemical Mfrs. Assn.

James A. Engman, Ansul Inc., WI [M]

John M. Eversole, Chicago Fire Dept., IL [E]
Rep. Int'l Assn. of Fire Chiefs

Remmit P. R. Gaade, Toronto Fire Dept., Ontario, Canada [E]

Joseph P. Gallagher, New York City Fire Dept., NY [E]

Gerald L. Grey, San Francisco Fire Dept., CA [U]
Rep. The Alliance for Fire and Emergency Mgmt.

H. Dieter Heinz, Heinz Laboratories Int'l, CA [E]
Rep. California State Firefighters' Assn.

John T. Higgins, Dow Corning Corp., MI [U]
Rep. NFPA Industrial Fire Protection Section

Charles L. Keller, Assn. of American Railroads, DC [E]

Louis J. Klein, Volunteer Firemens Insurance Services, PA [I]

Jan D. Kuczma, U.S. Fire Administration, MD [SE]

M. Jo McMullen, Summit County Hazardous Materials Response Team, OH [SE]

Mary Beth Michos, Prince William County Dept. of Fire/Rescue, VA [E]

Gregory G. Noll, Hildebrand & Noll Assoc., Inc., PA [SE]

Irving Owens, Rhode Island State Fire Marshal, RI [E]
Rep. Fire Marshals Assn. of North America

Daniel Gary Snell, Houston Fire Dept., TX [U]

William H. Stringfield, William H. Stringfield & Assoc., Inc., FL [SE]

Bruno Mark Wilson, Salem, OR [SE]

Charlie S. Woodard, Ft. Worth Fire Dept., TX [E]

Alternates

William Lee Bullock, Fairfax County Fire & Rescue Dept., VA [E]
(Alt. to G. P. Benarick)

Michael E. Burns, Michael E. Burns & Assoc., MD [M]
(Alt. to B. Berry)

Michael L. Donahue, Hildebrand and Noll Assoc., Inc., MD [SE]
(Alt. to G. Noll)

Leslie D. English, MacMillan Bloedel Packaging Inc., AL [U]
(Alt. to J. T. Higgins)

Brian S. Geraci, Montgomery County Dept. of Fire & Rescue Services, MD [E]
(Alt. to M. B. Michos)

Wilmuth E. Hubbs, Rhone-Poulenc, NC [M]
(Alt. to M. A. Ehrlich, Jr.

Philip H. McArdle, New York City Fire Dept., NY
(alt. to J.P. Gallagher)

Danny G. Simpson, Assn. of American Railroads, CO [RT]
(Alt. to J. C. Davis)

Paul R. Spurlin, Wayne Township Fire Dept., IN [E]
(Alt. to I. Owens)

Robert C. Weiderhold, Nat'l Fire Academy, MD [SE]
(Alt. to J. D. Kuczma)

Committee Scope: This Committee shall have primary responsibility for documents on the requirements for the professional competence, training, procedures, and equipment for emergency responders to hazardous materials incidents.

NFPA 473

Standard for Competencies for EMS Personnel Responding to Hazardous Materials Incidents

1997 Edition

NOTICE: An asterisk (*) following the number or letter designating a paragraph indicates that explanatory material on the paragraph can be found in Appendix A.
Information on referenced publications can be found in Chapter 4 and Appendix F.

Chapter 1 Administration

1-1 Scope.

This standard identifies the levels of competence required of emergency medical services (EMS) personnel who respond to hazardous materials incidents. It specifically covers the requirements for basic life support and advanced life support personnel in the prehospital setting.

1-2* Purpose.

The purpose of this standard is to specify minimum requirements of competence and to enhance the safety and protection of response personnel and all components of the emergency medical services system. It is not the intent of this standard to restrict any jurisdiction from exceeding these minimum requirements. (*See Appendix B.*)

1-3 Definitions.

Advanced Life Support (ALS).

Emergency Medical Technician-Paramedic (EMT-P). An individual who has successfully completed a course of instruction that meets or exceeds the requirements of the U.S. Department of Transportation National Standard EMT-Paramedic Curriculum and who holds an EMT-P certification from the authority having jurisdiction.

Emergency Medical Technician-Intermediate (EMT-I). (This category can include EMT-Cardiac.) An individual who has completed a course of instruction that includes selected modules of the U.S. Department of Transportation National Standard EMT-Paramedic Curriculum and who holds an intermediate level EMT-I or EMT-C certification from the authority having jurisdiction.

Authority Having Jurisdiction.* The organization, office, or individual responsible for approving equipment, an installation, or a procedure.

Basic Life Support (BLS).

*Emergency Medical Technician-Ambulance (EMT-A).** An individual who has completed a specified EMT-A course developed by the U.S. Department of Transportation and who holds an EMT-A certification from the authority having jurisdiction.

*Emergency Care First Responder (ECFR).** An individual who has successfully completed the specified Emergency Care First Responder course developed by the U.S. Department of Transportation and who holds an ECFR certification from the authority having jurisdiction.

Cold Zone. The control zone of a hazardous materials incident that contains the command post and such other support functions as are deemed necessary to control the incident. This zone is also referred to as the clean zone or support zone in other documents.

Competence. The possession of knowledge, skills, and judgment needed to perform indicated objectives satisfactorily.

Components of EMS System. The parts of a comprehensive plan to treat an individual in need of emergency medical care following an illness or injury. These parts include the following:

(a) First responders

(b) Emergency dispatching

(c) EMS agency response

(d) Hospital emergency departments

(e) Specialized care facilities

Confinement. Those procedures taken to keep a material, once released, in a defined or local area.

Contaminant. A hazardous material that physically remains on or in people, animals, the environment, or equipment, thereby creating a continuing risk of direct injury or a risk of exposure.

Control. The procedures, techniques, and methods used in the mitigation of a hazardous materials incident, including containment, extinguishment, and confinement.

Control Zones. Areas at a hazardous materials incident that are designated based on safety and the degree of hazard. Many terms are used to describe the zones involved in a hazardous materials incident. For purposes of this standard, these zones shall be defined as the hot, warm, and cold zones.

Decontamination (Contamination Reduction). The physical and/or chemical process of reducing and preventing the spread of contamination from persons and equipment involved in a hazardous materials incident.

Decontamination Area. The area, usually located within the warm zone, where decontamination takes place.

Demonstrate. To show by actual performance. This performance can be supplemented by simulation, explanation, illustration, or a combination of these.

Describe. To explain verbally or in writing using standard terms recognized in the hazardous materials response community.

Gross Decontamination. The initial phase of the decontamination process during which the amount of surface contaminant is significantly reduced. This phase can include mechanical removal and initial rinsing.

Hazard/Hazardous. Capable of posing an unreasonable risk to health, safety, or the environment; capable of doing harm.

Hazardous Materials.* A substance (solid, liquid, or gas) capable of creating harm to people, property, and the environment.

Class/Division. The general category of hazard assigned to a hazardous material under the DOT regulations. The division is a subdivision of a hazard class.

Class 1 (Explosives)

Division 1.1 Explosives with a mass explosion hazard

Division 1.2 Explosives with a projection hazard

Division 1.3 Explosives with predominantly a fire hazard

Division 1.4 Explosives with no significant blast hazard

Division 1.5 Very insensitive explosives

Division 1.6 Extremely insensitive explosives

Class 2

Division 2.1 Flammable gas

Division 2.2 Nonflammable, nonpoisonous compressed gas

Division 2.3 Poison gas

Division 2.4 Corrosive gas (Canadian designation)

Class 3 (Flammable Liquid)

Division 3.1 Flammable liquids, flashpoint <0°F

Division 3.2 Flammable liquids, flashpoint 0°F and above but <73°F

Division 3.3 Flammable liquids, flashpoint 73°F and up to 141°F

Combustible Liquid

Class 4

Division 4.1 Flammable solid

Division 4.2 Spontaneously combustible material

Division 4.3 Dangerous when wet material

Class 5

Division 5.1 Oxidizer

Division 5.2 Organic peroxide

Class 6

Division 6.1 Poisonous material

Division 6.2 Infectious material

Class 7 (Radioactive material)

Class 8 (Corrosive material)

Class 9 (Miscellaneous hazardous material)

ORM-D material

Hazardous Materials Response Team. The hazardous materials response team is an organized group of trained response personnel, operating under an emergency response plan and appropriate standard operating procedures, who handle and control actual or potential leaks or spills of hazardous materials requiring possible close approach to the material. The team members respond to releases or potential releases of hazardous materials for the purpose of control or stabilization of the incident.

High Temperature-Protective Clothing. Protective clothing designed to protect the wearer from short-term high temperature exposures. This type of clothing is usually of limited use in dealing with chemical commodities.

Hot Zone. The area immediately surrounding a hazardous materials incident, which extends far enough to prevent adverse effects from hazardous materials releases to personnel outside the zone. This zone is also referred to as the exclusion zone or restricted zone in other documents.

Identify. To select or indicate verbally or in writing using standard terms to establish the identity of; the fact of being the same as the one described.

Incident. An emergency involving the release or potential release of a hazardous material, with or without fire.

Incident Commander. The person responsible for all decisions relating to the management of the incident. The incident commander is in charge of the incident site. This term is equivalent to the on-scene incident commander.

Incident Management System. An organized system of roles, responsibilities, and standard operating procedures used to manage emergency operations, as described in NFPA 1561, *Standard on Fire Department Incident Management System*. Such systems are often referred to as “Incident Command Systems.”

Local Area. A geographic area that includes the defined response area and receiving facilities for an EMS agency.

Local Emergency Planning Committee (LEPC). (As mandated by SARA Title III.) Includes elected state and local officials, police, fire, civil defense, public health professionals, environmental, hospital, and transportation officials as well as representatives of facilities, community groups, and the media.

Medical Control. The physician providing direction for patient care activities in the prehospital setting.

Medical Surveillance. The ongoing process of medical evaluation of hazardous materials response team members and public safety personnel who respond to a hazardous materials incident.

Objective. A goal that is achieved through the attainment of a skill, knowledge, or both, that can be observed or measured.

Personal Protective Equipment. The equipment provided to shield or isolate a person from the chemical, physical, and thermal hazards that can be encountered at a hazardous materials incident. Personal protective equipment includes both personal protective clothing and respiratory protection. Adequate personal protective equipment should protect the respiratory system, skin, eyes, face, hands, feet, head, body, and hearing.

Protective Clothing. Equipment designed to protect the wearer from the heat and/or hazardous materials that might contact the skin or eyes. Protective clothing is divided into the following three types:

(a) Chemical-protective clothing

1. Liquid splash-protective clothing

2. Vapor-protective clothing

(b) High temperature-protective clothing

(c) Structural fire fighting protective clothing

Protocol. A series of sequential steps describing the precise patient treatment.

Region. A geographic area that includes the local and neighboring jurisdiction for an EMS agency.

Respiratory Protection. Equipment designed to protect the wearer from the inhalation of contaminants. Respiratory protection is divided into the following three types:

(a) Positive pressure self-contained breathing apparatus

(b) Positive pressure air line respirators

(c) Air purifying respirators

Safely. To perform the objective without injury to self or others, property, or the environment.

Secondary Contamination.* The transfer of contaminants to personnel or equipment outside the hot zone.

Shall. Indicates a mandatory requirement.

Should. Indicates a recommendation or that which is advised but not required.

Termination. That portion of incident management in which personnel are involved in documenting safety procedures, site operations, hazards faced, and lessons learned from the incident. Termination is divided into three phases: debriefing the incident, post-incident analysis, and critiquing the incident.

Understanding. The process of gaining or developing the meaning of various types of materials or knowledge.

Warm Zone. The area where personnel and equipment decontamination and hot zone support takes place. It includes control points for access corridor and thus assists in reducing the spread of contamination. This is also referred to as the decontamination, contamination reduction, or limited access zone in other documents.

Chapter 2 Competencies for EMS/HM Level I Responders

2-1 General.

2-1.1 Introduction.

All EMS personnel at EMS/HM Level I, in addition to their BLS or ALS certification, shall be trained to meet at least the first responder awareness level as defined in NFPA 472, *Standard for Professional Competence of Responders to Hazardous Materials Incidents*, and all competencies of this chapter.

2-1.2* Definition.

EMS personnel at EMS/HM Level I are those persons who, in the course of their normal duties, might be called on to perform patient care activities in the cold zone at a hazardous materials incident. EMS/HM Level I responders shall provide care only to those individuals who no longer pose a significant risk of secondary contamination.

2-1.3 Goal.

The goal of the competencies at EMS/HM Level I shall be to provide the individual with the knowledge and skills necessary to safely deliver emergency medical care in the cold zone. Therefore the EMS/HM Level I responder shall be able to:

(a) Analyze a hazardous materials emergency to determine what risks are present to the provider and the patient by completing the following tasks:

1. Determine the hazards present to the Level I responder and the patient in a hazardous materials incident

2. Assess the patient to determine the risk of secondary contamination

(b) Plan a response to provide the appropriate level of emergency medical care to persons involved in hazardous materials incidents by completing the following tasks:

1. Describe the role of the Level I responder in a hazardous materials incident

2. Plan a response to provide the appropriate level of emergency medical care in a hazardous materials incident

3. Determine if the personal protective equipment provided is appropriate

4. Determine if the equipment and supplies provided are adequate

(c) Implement the planned response by completing the following tasks:

1. Perform the necessary preparations for receiving the hazardous materials patient and preventing secondary contamination

2. Treat the hazardous materials patient

3. Transport the patient as appropriate

(d) Terminate the incident

2-2 Competencies — Analyzing the Hazardous Materials Incident.

2-2.1

Given an emergency involving hazardous materials, the Level I responder shall determine the hazards to the responder and the patient in that situation. The Level I responder shall be able to:

(a) Assess the nature and severity of the incident (size-up) as they pertain to EMS responsibilities at a hazardous materials incident with evaluation of available resources and a request for any needed assistance

(b) Evaluate the environmental factors as they affect patient care

(c) Identify the information resources available and how to access the following:

1. Poison Control Center

2. Medical control

3. Material safety data sheets

4. Reference guidebooks

5. Hazardous materials data bases

6. Technical information centers (CHEMTREC, NRC, etc.)

7. Technical specialists

8. Agency for Toxic Substances and Disease Registry (ATSDR)

(d) Given a pesticide label, identify and explain the significance of the following:

1. Name of pesticide

2. Signal word

3. EPA registration number

4. Precautionary statement

5. Hazard statement

6. Active ingredient

2-2.2

Given a hazardous materials incident with a patient(s), the Level I responder shall determine the risk of secondary contamination. The Level I responder shall be able to:

(a) Explain the basic toxicological principles relative to assessment and treatment of victims exposed to hazardous materials, including the following:

1. Acute and delayed toxicity

2. Routes of exposure to toxic materials

3. Local and systemic effects

4. Dose response as it relates to risk assessment

5.* Synergistic effects

6. Health hazard as determined by assessing toxicity, exposure, and dose

(b) Describe how the chemical contamination of patients alters the principles of triage in hazardous materials incidents

(c) Explain the need for patient decontamination procedures at hazardous materials incidents

(d) Describe how the potential for secondary contamination determines the extent of patient decontamination required

(e) Describe the way that personnel, personal protective clothing, apparatus, tools, and equipment become contaminated and the importance and limitations of decontamination procedures

(f) Explain the decontamination procedures as defined by the authority having jurisdiction for patients, personnel, personal protective equipment, and apparatus at hazardous materials incidents

2-3 Competencies — Planning the Response.

2-3.1

Given a plan of action by the incident commander, the Level I responder shall describe their role in a hazardous materials incident as identified in the local emergency response plan or organization's standard operating procedures, including the following:

(a) Describe the emergency medical component for the hazardous materials incident response plan as developed by the authority having jurisdiction

(b) State the Level I responder's role within the hazardous materials response plan as developed by the authority having jurisdiction

(c) State the Level I responder's role within the hazardous materials incident management system

2-3.2

Given a hazardous materials incident, the Level I responder shall be able to plan a response to provide the appropriate level of emergency medical care, including the standard operating procedures for the medical management of persons exposed to hazardous materials, as specified by the authority having jurisdiction.

2-3.3

Given the name of the hazardous material and the type, duration, and extent of exposure and decontamination process, the Level I responder shall determine if available personal protective clothing and equipment are appropriate to implement the planned response. The Level I responder shall be able to:

(a) Describe the application, use, and limitations of the following:

1. Street clothing and work uniforms
2. Structural fire fighting protective clothing
3. Respiratory protective equipment
4. Chemical-protective clothing

2-3.4

Given a simulated hazardous materials incident, the Level I responder shall determine if available equipment and supplies are appropriate to implement the planned response. The Level I responder shall be able to describe the equipment and supplies available to the Level I responder for the care and transportation of the hazardous materials incident patient.

2-4 Competencies — Implementing the Planned Response.

2-4.1

Given a plan for providing patient care at a hazardous materials incident, the Level I responder shall be able to perform the preparations necessary to receive the patient for treatment and transport. The Level I responder shall be able to:

(a) List the information that needs to be communicated to the Medical Control/Receiving facility regarding the hazardous materials incident, including the following:

1. Type and nature of the incident
2. Chemical involved and its physical state
3. Number of potential patients

(b) Describe the procedure for preparing the vehicle and equipment for the patient

(c) Demonstrate the proper donning, doffing, usage, and limitations of all personal protective equipment provided to the Level I responder by the authority having jurisdiction for use in their hazardous materials response activities

(d) Describe the concept of patient transfer from the incident site to the decontamination area and then to the treatment area

2-4.2

Given a patient from a hazardous materials incident, the Level I responder shall provide patient care consistent with the planned response and the organization’s standard operating procedures. The Level I responder shall be able to:

(a) Describe how chemical contamination alters the assessment and care of the hazardous materials patient

(b) List the common signs and symptoms and describe the EMS treatment protocols for the following:

1. Corrosives (e.g., acid, alkali)
2. Pulmonary irritants (e.g., ammonia, chlorine)
3. Pesticides (e.g., organophosphates, carbamates)
4. Chemical asphyxiants (e.g., cyanide, carbon monoxide)
5. Hydrocarbon solvents (e.g., xylene, methylene chloride)

(c) Explain the potential risk with invasive procedures for hazardous materials patients

(d) Demonstrate the ability to perform the following EMS functions within the incident management system during incidents involving multiple hazardous materials patients:

1.* EMS control

2. Triage

3. Treatment

4. Disposition and transportation

2-4.3

Given a patient from a hazardous materials incident, the Level I responder shall transport the patient as specified in the local emergency response plan and the organization’s standard operating procedures. The Level I responder shall be able to:

(a) Identify the capabilities of the medical facilities available in the local area to receive hazardous materials patients

(b) Identify the acceptable vehicles available to transport hazardous materials patients from the treatment area to a receiving facility

(c) List the pertinent information that needs to be communicated to the receiving facility, including the following:

1. Estimated time of arrival
2. Age/sex
3. Patient condition/chief complaint

4. Associated injuries

5. Routes, extent, and duration of chemical exposure

6. Pertinent medical history

7. Signs and symptoms

8. Vital signs

9. Treatment, including decontamination and patient response

10. Pertinent chemical characteristics

(d) Describe the actions necessary for the coordinated delivery of hazardous materials incidents patients to a receiving facility

(e) Explain the special hazards associated with air transportation of patients exposed to hazardous materials

2-5 Competencies — Terminating the Incident.

2-5.1

Upon termination of the hazardous materials incident, the Level I responder shall complete the reporting, documentation, and EMS termination activities as required by the local emergency response plan or the organization's standard operating procedures. The Level I responder shall be able to:

(a) List the information to be gathered regarding the exposure of the patient and the EMS provider and describe the proper reporting procedures, including the following:

1. Product information

2. Routes, extent, and duration of exposure

3. Actions taken to limit exposure and contamination

4. Treatment rendered

5. Patient condition and disposition

(b) Identify situations that can necessitate critical incident stress debriefing intervention

(c) Describe the EMS provider's role in the post-incident critique

Chapter 3 Competencies for EMS/HM Level II Responders

3-1 General.

3-1.1 Introduction.

All personnel at EMS/HM Level II shall be certified to the EMT-A level or higher and shall meet all competencies for EMS/HM Level I in addition to all the competencies of this chapter.

3-1.2 Definition.

Personnel at EMS/HM Level II are those persons who, in the course of their normal activities, might be called upon to perform patient care activities in the warm zone at hazardous materials incidents. EMS/HM Level II responder personnel might be required to provide care to those individuals who still pose a significant risk of secondary contamination. In addition, personnel at this level shall be able to coordinate EMS activities at a hazardous materials incident and provide medical support for hazardous materials response personnel.

3-1.3 Goal.

The goal of the competencies at EMS/HM Level II shall be to provide the Level II responder with the knowledge and skills necessary to perform and/or coordinate patient care activities and medical support of hazardous materials response personnel in the warm zone. Therefore the Level II responder shall be able to:

(a) Analyze a hazardous materials incident to determine the magnitude of the problem in terms of outcomes by completing the following tasks:

1. Determine the hazards present to the Level II responder and the patient in a hazardous materials incident

2. Assess the patient to determine the patient care needs and the risk of secondary contamination

(b) Plan a response to provide the appropriate level of emergency medical care to persons involved in hazardous materials incidents and to provide medical support to hazardous materials response personnel by completing the following tasks:

1. Describe the role of the Level II responder in a hazardous materials incident

2. Plan a response to provide the appropriate level of emergency medical care in a hazardous materials incident

3. Determine if the personal protective equipment provided to EMS personnel is appropriate

(c) Implement the planned response by completing the following tasks:

1. Perform the necessary preparations for receiving the patient

2. Perform necessary treatment to the hazardous materials patient

3. Coordinate and manage the EMS component of the hazardous materials incident

4. Perform medical support of hazardous materials incident response personnel

(d) Terminate the incident

3-2 Competencies — Analyzing the Hazardous Materials Incident.

3-2.1

Given an emergency involving hazardous materials, the Level II responder shall determine the hazards to the responders and the patient in that situation. The Level II Responder shall be able to:

(a) Define the following chemical and physical properties and describe their importance in the risk assessment process:

1. Boiling point
2. Flammable (explosive) limits
3. Flash point
4. Ignition temperature
5. Specific gravity
6. Vapor density
7. Vapor pressure
8. Water solubility

(b) Define the following terms:

1. Alpha radiation
2. Beta radiation
3. Gamma radiation

(c) Define the following toxicological terms and explain their use in the risk assessment process:

1. Threshold limit value (TLV-TWA)
2. Lethal concentration and doses ($LD_{50/100}$)
3. Parts per million/billion (ppm/ppb)
4. Immediately dangerous to life and health (IDLH)
5. Permissible exposure limit (PEL)
6. Short-term exposure limit (TLV-STEL)
7. Ceiling level (TLV-C)

(d) Given a specific hazardous material and using the information sources available to the Level II responder, demonstrate extracting appropriate information about the physical characteristics and chemical properties, hazards, and suggested medical response considerations for that material

3-2.2

Given a hazardous materials incident with a patient(s), the Level II responder shall assess the patient and conditions to determine the risk of secondary contamination. The Level II responder shall be able to:

(a) Identify sources of technical information for the performance of patient decontamination

(b) Identify the factors that influence the decision of when and where to treat the patient and the extent of patient care, including the following:

1. Hazardous material toxicity
2. Patient condition

3. Availability of decontamination

3-3 Competencies — Planning the Response.

3-3.1

Given a plan of action by the incident commander, the Level II responder shall describe his or her role in a hazardous materials incident as identified in the local emergency response plan or the organization's standard operating procedures. The Level II responder shall be able to describe the importance of coordination between various agencies at the scene of hazardous materials incidents.

3-3.2

Given a hazardous materials incident, the Level II responder shall plan a response to provide the appropriate level of emergency medical care to persons involved in hazardous materials incidents and to provide medical support to hazardous materials response personnel. The Level II responder shall be able to:

(a) Given a simulated hazardous materials incident, assess the problem and formulate and implement a plan including the following:

1. EMS control activities

2. EMS component of an incident management system

3. Medical monitoring of personnel utilizing chemical-protective and high temperature-protective clothing

4. Triage of hazardous materials victims

5. Medical treatment for chemically contaminated individuals

6. Product and exposure information gathering and documentation

(b) Describe the importance of pre-emergency planning relating to specific sites

(c) Describe the hazards and precautions to be observed when approaching a hazardous materials incident

(d) Describe the considerations associated with the placement, location, and setup of the patient decontamination site

(e) Explain the advantages and limitations of the following techniques of decontamination and how they are or are not applicable to patient decontamination:

1. Absorption

2. Chemical degradation

3. Dilution

4. Isolation

(f) Describe when it would be prudent to pull back from a hazardous materials incident

3-3.3

Given the name of the hazardous material and the type, duration, and extent of exposure, the Level II responder shall determine if the protective clothing and equipment available to EMS personnel is appropriate to implement the planned response. The Level II responder shall be able to:

(a) Identify the advantages and dangers of search and rescue missions at hazardous materials incidents

(b) Identify the advantages and hazards associated with the rescue, extrication, and removal of a victim from a hazardous materials incident

(c) Describe the types, application, use, and limitations of protective clothing used by EMS personnel at hazardous materials incidents

(d) Demonstrate how to interpret a chemical compatibility chart for chemical-protective clothing

3-4 Competencies — Implementing the Planned Response.

3-4.1

Given a plan for providing patient care at a hazardous materials incident, the Level II responder shall perform the preparations necessary to receive the patient for treatment and transport. The Level II responder shall be able to demonstrate the proper donning, doffing, and usage of all personal protective equipment provided to the Level II responder by the authority having jurisdiction.

3-4.2

At the scene of a hazardous materials incident, the Level II responder shall be able to provide or coordinate the patient care. The Level II responder shall be able to:

(a) Given a simulated hazardous materials incident and using local available resources, demonstrate the implementation of the patient decontamination procedure (*see Appendix E*)

(b) Explain the principles of emergency decontamination and its application for critically ill patients

(c) Demonstrate the ability to coordinate patient care activities, including treatment, disposition, and transportation of patients

3-4.3

Given a simulated hazardous materials incident, the Level II responder shall be able to demonstrate the ability to establish and manage the EMS component of an incident management system.

3-4.4

Given a simulated hazardous materials incident, the Level II responder shall perform medical support of hazardous materials incident response personnel. The Level II responder shall be able to:

(a) Explain the components of pre-entry and post-entry assessment, including the following:

1. Vital signs

2. Body weight

3. General health

4. Neurological status

5. Electrocardiographic rhythm strip, if available

(b) Explain the following factors and how they influence heat stress for hazardous materials response personnel:

1. Hydration

2. Physical fitness

3. Environmental factors

4. Activity levels

5. Level of PPE

6. Duration of entry

(c) Explain the medical monitoring protocols and demonstrate medical monitoring procedures for personnel at the scene of a hazardous materials incident

(d) Describe the criteria for site selection of a medical monitoring station

(e) Demonstrate the ability to set up and operate a medical monitoring station

(f) Demonstrate the ability to interpret and analyze data obtained from medical monitoring of hazardous materials response personnel

(g) Given a simulated hazardous materials incident, demonstrate proper documentation of medical monitoring

3-5 Competencies — Terminating the Incident.

3-5.1

Upon termination of the hazardous materials incident, the Level II responder shall complete the reporting, documentation, and EMS termination activities as required by the local emergency response plan or the organization's standard operating procedures. The Level II responder shall be able to:

(a)* Describe the information regarding incident EMS activities that needs to be relayed through the chain of command to the incident commander

(b) Describe the activities required in terminating the EMS component of a hazardous materials incident

(c) Describe the process and demonstrate the ability to conduct the EMS portion of an incident critique

(d) Explain the process of making revisions to EMS operating procedures and response capabilities as a result of information learned

Chapter 4 Referenced Publications

4-1

The following documents or portions thereof are referenced within this standard as mandatory requirements and shall be considered part of the requirements of this standard. The edition indicated for each referenced mandatory document is the current edition as of the date of the NFPA issuance of this standard. Some of these mandatory documents might also be referenced in this standard for specific informational purposes and, therefore, are also listed in Appendix F.

4-1.1 NFPA Publications.

National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.

NFPA 472, *Standard for Professional Competence of Responders to Hazardous Materials Incidents*, 1997 edition.

NFPA 1561, *Standard on Fire Department Incident Management System*, 1995 edition.

Appendix A Explanatory Material

This appendix is not a part of the requirements of this NFPA document but is included for informational purposes only.

A-1-2 The competency requirements for EMS personnel contained herein have been prepared to reduce the numbers of accidents, exposures, and injuries resulting from hazardous materials incidents.

A-1-3 Authority Having Jurisdiction. The phrase "authority having jurisdiction" is used in NFPA documents in a broad manner, since jurisdictions and approval agencies vary, as do their responsibilities. Where public safety is primary, the authority having jurisdiction may be a federal, state, local, or other regional department or individual such as a fire chief; fire marshal; chief of a fire prevention bureau, labor department, or health department; building official; electrical inspector; or others having statutory authority. For insurance purposes, an insurance inspection department, rating bureau, or other insurance company representative may be the authority having jurisdiction. In many circumstances, the property owner or his or her designated agent assumes the role of the authority having jurisdiction; at government installations, the commanding officer or departmental official may be the authority having jurisdiction.

A-1-3 Basic Life Support (BLS). *Emergency Medical Technician-Ambulance (EMT-A)*. This level in some jurisdictions may be recognized as EMT-Basic (EMT-B).

A-1-3 Basic Life Support (BLS). *Emergency Care First Responder (ECFR)*. In Canada, the terminology used is: Emergency Medical Assistant-1 (EMA-1), Emergency Medical Assistant-2 (EMA-2), and Emergency Medical Assistant-3 (EMA-3).

A-1-3 Hazardous Materials. There are many definitions and descriptive names being used for the term hazardous materials, each of which depends on the nature of the problem being addressed.

Unfortunately, there is no one list or definition that covers everything. The United States agencies involved, as well as state and local governments, have different purposes for regulating hazardous materials that, under certain circumstances, pose a risk to the public or the environment.

(a) *Hazardous Materials.* The United States Department of Transportation (DOT) uses the term *hazardous materials*, which covers eight hazard classes, some of which have subcategories called classification, and a ninth class covering other regulated materials (ORM). DOT includes in its regulations hazardous substances and hazardous wastes as an ORM-E, both of which are regulated by the Environmental Protection Agency (EPA), if their inherent properties would not otherwise be covered.

(b) *Hazardous Substances.* EPA uses the term *hazardous substances* for the chemicals that, if released into the environment above a certain amount, must be reported and, depending on the threat to the environment, for which federal assistance in handling the incident can be authorized. A list of the hazardous substances is published in Title 40, *Code of Federal Regulations*, Part 302, Table 302.4.

(c) *Extremely Hazardous Substances.* EPA uses the term *extremely hazardous substances* for chemicals that must be reported to the appropriate authorities if released above the threshold reporting quantity. Each substance has a threshold reporting quantity. The list of extremely hazardous substances is identified in Title III of Superfund Amendments and Reauthorization Act (SARA) of 1986 (Title 40, *Code of Federal Regulations*, Part 355).

(d) *Toxic Chemicals.* EPA uses the term *toxic chemicals* for chemicals whose total emissions or releases must be reported annually by owners and operators of certain facilities that manufacture, process, or otherwise use a listed toxic chemical. The list of toxic chemicals is identified in Title III of SARA.

(e) *Hazardous Wastes.* EPA uses the term *hazardous wastes* for chemicals that are regulated under the Resource, Conservation and Recovery Act (Title 40, *Code of Federal Regulations*, Part 261.33). Hazardous wastes in transportation are regulated by DOT (Title 49, *Code of Federal Regulations*, Parts 170-179).

(f) *Hazardous Chemicals.* The United States Occupational Safety and Health Administration (OSHA) uses the term *hazardous chemicals* to denote any chemical that would be a risk to employees if exposed in the workplace. Hazardous chemicals cover a broader group of chemicals than the other chemical lists.

(g) *Hazardous Substances.* OSHA uses the term *hazardous substances* in Title 29, *Code of Federal Regulations*, Part 1910.120, which resulted from Title I of SARA and covers emergency response. OSHA uses the term differently than EPA. Hazardous substances, as used by OSHA, cover every chemical regulated by both DOT and EPA.

A-1-3 Secondary Contamination. A substance is considered to pose a serious risk of secondary contamination if it is likely to be carried on equipment, clothing, skin, or hair in sufficient quantities to be capable of harming personnel outside of the hot zone.

A-2-1.2 See Appendix D.

A-2-2.2(a)5 As defined in Webster's Dictionary, the word *synergism* means "a cooperative action of discrete agencies such that the total effect is greater than the sum of the effects taken independently." In the context of hazardous materials, it is important to remember that the signs and symptoms of a given chemical are generally standard for that particular chemical. But when two or more chemicals are involved, the resultant signs and symptoms from an exposure may be dramatically different than what the EMS provider anticipates.

A-2-4.2(d)1 EMS control activities at a hazardous materials incident include, but are not limited to, the following:

(a) Identification of EMS needs, including appropriate level of protection for EMS personnel and equipment, resources for patient care, and decontamination of patient and EMS personnel

(b) Securing of resources to meet EMS needs

(c) Assignment of personnel, in the cold zone, to coordinate triage, treatment, disposition, and transport as required

(d) Assignment of appropriately trained personnel to perform medical monitoring and other EMS support functions for hazardous materials response personnel in the cold zone

(e) Assignment of appropriately trained personnel to provide patient care, assist with patient decontamination, and perform any other EMS support functions, as may be required in the warm zone

A-3-5.1(a) The type of information that should be made available to the incident commander would include, but not necessarily be limited to, the following:

(a) Patients

1. Number
2. Condition
3. Disposition

(b) Hazardous materials response personnel

1. Number of personnel screened
2. Adverse reactions noted
3. Personnel transported for further treatment
4. Completed records
5. Recommended medical, physical, and psychological needs for immediate rehabilitation
6. Recommended medical surveillance follow-up

(c) Availability of EMS personnel and equipment

Appendix B Training

This appendix is not a part of the requirements of this NFPA document but is included for informational purposes only.

B-1 General. The Emergency Medical Services (EMS) personnel responding to hazardous materials incidents should be trained and should receive regular continuing education to maintain competency in three areas: emergency medical technology, hazardous materials, and specialized topics approved by the authority having jurisdiction.

B-1.1 EMS Training. Recognized US DOT, state, regional, or local training curricula should constitute the entry level EMS preparation for continuing hazardous materials training. At a hazardous materials incident it is desirable that all EMS BLS provider personnel be trained to the US DOT EMT-A level or equivalent.

B-1.2 Hazardous Materials Training. The foundation for EMS response to a hazardous materials incident should be the competencies described in NFPA 472, *Standard for Professional Competence of Responders to Hazardous Materials Incidents*.

B-1.3 Specialized Training. Following completion of approved EMS training and appropriate level of hazardous materials instruction described in this standard, the authority having jurisdiction should stipulate additional specialized instruction that the EMS personnel responding to hazardous materials incidents must complete.

B-2 Training Plan.

B-2.1 The authority having jurisdiction should develop a formal training plan and provide a program to train EMS personnel to the level being utilized.

B-2.2 A training plan should be developed and contain guidelines for the following functional categories:

(a) Program management

(b) Content development

(c) Instructor competencies

(d) Technical specialist competencies

B-2.3 The training plan should be criteria-based to maintain a consistent quality of curriculum and instruction.

B-2.4 The training plan should specify entry knowledge and skill levels, training, and refresher training for both students and instructors.

B-2.5 The training plan should define evaluation criteria for successful completion of knowledge and skill objectives of the training program.

B-2.6 The training plan should provide for supervised field experience for EMS hazardous materials responder and EMS hazardous materials coordinator training levels.

B-3 Training Program. The training program should be a comprehensive competency-based guideline of the implementation and presentation of the required subject material. As a minimum it should address the areas discussed in this section.

B-3.1 Program Manager.

B-3.1.1 The program manager should have the authority and responsibility for the overall implementation of the program.

B-3.1.2 The program manager should be able to demonstrate knowledge of the following:

(a) The content of NFPA 472, *Standard for Professional Competence of Responders to Hazardous Materials Incidents*; NFPA 471, *Recommended Practice for Responding to Hazardous Materials Incidents;* and this standard

(b) EMS delivery systems

(c) Budgeting and financial planning

(d) Processes used to develop instructional materials

B-3.1.3 The program manager should demonstrate the skill and ability to perform the following tasks:

(a) Coordinate the training program

(b) Evaluate program effectiveness

(c) Identify instructors and technical specialists

B-3.2 Content. The content of the training program should include the competencies of this standard as a minimum.

B-3.3 Evaluation. In recognition of the need for technically sound curricula and instruction to meet the competencies outlined in this standard, careful evaluation of all instructors' training, background, and experience should be made.

B-3.3.1 The authority having jurisdiction should ensure that the training program meets the needs of the local area.

B-3.3.2 The program manager should ensure that the training program meets the needs of the hazardous materials response team and the EMS providers.

B-4 Instruction. The need exists for technically sound curricula and delivery to meet the competencies outlined in this standard.

B-4.1 Instructors. The instructor should

(a) Have mastery of the material he/she presents

(b) Have an understanding of the training program objectives

(c) Have the ability to teach and evaluate

B-4.2 Technical Specialist. The technical specialist is a person who has technical expertise and practical knowledge in a specific area. This category is intended to support training activities by allowing individuals not otherwise qualified at the instructor level to present an essential segment for which they do have expertise.

B-4.3 Final Evaluation. Upon completion of the training program, the student should demonstrate competency in all prescribed content areas. This evaluation should include written and practical testing as specified by the program manager and instructors.

Appendix C Recommended Support Resources

This appendix is not a part of the requirements of this NFPA document but is included for informational purposes only.

C-1 General. Emergency medical service personnel who respond to hazardous materials incidents must operate within a network of support resources. This appendix addresses the general classes of these resources and presents a recommended minimum level of support necessary for adequate emergency medical response.

C-2 Poison Control Centers (PCC).

C-2.1 Goal. In addition to providing support to the general hazardous materials response, the goal of the Poison Control Center is to provide the emergency medical personnel who respond to hazardous materials incidents with medical guidance, information, and advice during incidents involving toxic chemical releases and associated injuries. The PCC should regularly participate in the following activities together with the EMS component of the hazardous materials incident response.

C-2.1.1 Preplanning Assistance. Poison Control Centers should provide preplanning assistance, including the following:

(a) Training

(b) EMS hazardous materials standard operating procedures review

(c) EMS reference materials

C-2.1.2 Technical Advice. Poison Control Centers should have the ability to coordinate decontamination, treatment, and transportation of injured persons. The PCC should be available to the EMS personnel who respond to hazardous materials incidents for emergency consultation around the clock and during the normal working hours for nonemergency consultation. Poison Control Centers should be capable of providing advice regarding the following areas:

(a) Identity of ingredients

(b) Toxicity of substances involved and symptoms and signs of exposure

(c) Recommended level of protective clothing

(d) Potential for secondary contamination

(e) Recommended decontamination procedures

(f) Specific treatment and/or antidotes

C-2.1.3 Data Bases. The PCC should supervise and review the EMS data bases used during hazardous materials incident response.

C-2.1.4 Medical Surveillance. The PCC should provide support for the following:

(a) Surveillance quality assurance program design

(b) Surveillance Q/A program review

(c) Medical follow-up activities

C-3 Chemical Injury Treatment Centers.

C-3.1 Goal. The emergency medical responders to hazardous materials incidents should transfer chemically injured patients to facilities having adequate chemical injury treatment capability. All such facilities should have a minimum level of competency to receive chemically injured patients, including the following provisions.

C-3.1.1 Patient Decontamination Capabilities. Facilities should have the following resources in order to perform patient decontamination:

(a) Decontamination area

(b) Proper ventilation system

(c) Restricted access

(d) Runoff containment

C-3.1.2 Facilities should provide a cadre of trained in-house hazardous materials incident injury treatment personnel.

C-3.1.3 Chemical injury treatment centers should have on hand personal protective clothing for hospital personnel that may treat hazardous materials patients.

C-3.1.4 All treatment centers should have formal hazardous materials incident response procedures directed to EMS providers and hospital personnel.

C-4 Communications. The network of emergency medical response resources to hazardous materials incidents should be linked by an adequate communication system within the incident command post. The following components are suggested as a minimum.

C-4.1 Radiotelephone. All mobile and fixed EMS components should be able to coordinate EMS hazardous materials incident response via at least one dedicated frequency. All fixed facilities shall have r-f emergency power capability for at least one radio channel.

C-4.2 Telephone Service. There should be telephone service within the Medical Section/Division; preferably a cellular telephone.

C-4.3 Computer. All components of the EMS hazardous materials incident response system should have an orientation to and direct or indirect access to computerized chemical data bases, computerized preplans, and computerized operational command and control.

C-4.3.1 Fixed Installation. Computer generated information should be readily available to field and clinical EMS hazardous materials response personnel via at least two of the following:

(a) Verbal transmission

(b) Fax transmission

(c) Modem transmission

C-4.3.2 Mobile. On-scene EMS response personnel should have immediate direct access to a field computerized highly toxic hazardous materials data base and computerized command and control information.

C-4.4 Other Resources. Additional response resources available to hazardous materials incidents include the following:

(a) CHEMTREC (CMA)

(b) ATSDR (HHS)

(c) Private resources

Appendix D Medical Treatment Considerations

This appendix is not a part of the requirements of this NFPA document but is included for informational purposes only.

D-1 The assessment and prehospital care of patients who are involved in hazardous materials incidents, and who are potentially chemically contaminated, should include the following steps:

(a) The safety of the EMS provider should be provided for by securing the scene, ensuring appropriate decontamination of the patient, and protecting against exposure to communicable diseases and hazardous materials.

(b) The patient's airway should be secure and regularly monitored.

(c) The patient's breathing should be monitored and assisted when necessary.

(d) Supplemental oxygen should be administered if the surrounding environment safely permits.

(e) Bleeding should be controlled. This may be accomplished by the application of pressure bandages. Lower extremity bleeding may be controlled through the use of pneumatic anti-shock garments.

(f) When trauma may have involved cervical spine injury, an appropriate stabilization, immobilization collar should be applied.

(g) Cardiopulmonary resuscitation should be performed, if indicated.

(h) In general, avoid all prophylactic invasive procedures unless required by life-threatening conditions. This includes the establishment of intravenous lines.

(i) Direct medical control should be established.

The authority having jurisdiction should ensure that a written prehospital medical standard operating procedures protocol is in place to provide direction to EMS personnel who respond to hazardous materials incidents.

Appendix E Patient Decontamination

This appendix is not a part of the requirements of this NFPA document but is included for informational purposes only.

E-1 Patient decontamination, if required, should be carried out in the warm zone by properly trained personnel wearing appropriate chemical-protective clothing and respiratory equipment.

Protocol(s) should be written to address the following:

(a) Determination of the potential for secondary contamination and the necessity for, and extent of, decontamination

(b) Selection of appropriate personal protective equipment to be worn by personnel in the warm zone who are assisting with or performing decontamination

(c) Decontamination of patients when the exposure is to an unidentified gas, liquid, or solid material

(d) Emergency decontamination of patients with critical injuries and illness requiring immediate patient care or transport

Appendix F Referenced Publications

F-1 The following documents or portions thereof are referenced within this standard for informational purposes only and are thus not considered part of the requirements of this standard unless also listed in Chapter 4. The edition indicated here for each reference is the current edition as of the date of the NFPA issuance of this standard.

F-1.1 NFPA Publications. National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.

NFPA 471, *Recommended Practice for Responding to Hazardous Materials Incidents*, 1997 edition.

NFPA 472, *Standard for Professional Competence of Responders to Hazardous Materials Incidents*, 1997 edition.

F-1.2 Other Publications.

F-1.2.1 U.S. Government Publications. U.S. Government Printing Office, Superintendent of Documents, Washington, DC 20402.

Title 29, *Code of Federal Regulations*, Part 1910.120

Title 40, *Code of Federal Regulations*, Part 261.33

Title 40, *Code of Federal Regulations*, Part 302

Title 40, *Code of Federal Regulations*, Part 355

Title 49, *Code of Federal Regulations*, Parts 170-179

F-2 The following documents are not referenced within this standard, but may be useful to the reader.

Poisoning and Drug Overdose, Kent R. Olson, M.D., ed, Appleton & Lange, Norwalk, CT, 1990.

Borak, Jonathan, Michael Callan, and William Abbot. *Hazardous Materials Exposure: Emergency Response and Patient Care.* Englewood Cliffs, NJ: Prentice Hall, 1991.

Bronstein, Alvin C., and Phillip L. Currance. *Emergency Care for Hazardous Materials Exposure*, 2nd ed. St. Louis: Mosby Lifeline, 1994.

NFPA 480

1993 Edition

Standard for the Storage, Handling, and Processing of Magnesium Solids and Powders

1993 Edition

This edition of NFPA 480, *Standard for the Storage, Handling, and Processing of Magnesium Solids and Powders*, was prepared by the Technical Committee on Combustible Metals and Metal Dusts and acted on by the National Fire Protection Association, Inc. at its Annual Meeting held May 24-27, 1993, in Orlando, FL. It was issued by the Standards Council on July 23, 1993, with an effective date of August 20, 1993, and supersedes all previous editions.

The 1993 edition of this document has been approved by the American National Standards Institute.

Origin and Development of NFPA 480

This standard was begun in 1946, tentatively adopted in 1950, and adopted by the National Fire Protection Association in May, 1951. Revisions were adopted by the Association in 1952, 1954, 1957, 1959, 1961, and 1967. The 1967 edition was reconfirmed in 1974.

The 1974 edition was completely revised in 1980, primarily to comply with the NFPA *Manual of Style*. Minor technical amendments were made at that time. This complete revision of the 1974 edition was acted on by the Association at its 1981 Fall Meeting and the revision was designated the 1982 edition.

The 1987 edition was a reconfirmation of the 1982 edition. The only changes made were minor editorial improvements and redesignation of the standard as NFPA 480.

For this 1993 edition, the Committee has completely revised the standard to update the requirements for safe handling of magnesium solids and powders as well as updating the fire and dust explosion prevention measures for both. The Committee has incorporated the requirements for safe handling of magnesium powder that were previously found in the 1987 edition of NFPA 651, *Standard for the Manufacture of Aluminum and Magnesium Powder*. The Committee revision has also incorporated editorial and style revisions to comply with the NFPA *Manual of Style* and to assist in making the document more usable, adoptable, and enforceable.

Technical Committee on Combustible Metals and Metal Dusts

Robert W. Nelson, *Chair*
Industrial Risk Insurers, CT
Rep. Industrial Risk Insurers

Richard J. Biehl, Ansul Fire Protection, WI
Rep. Fire Equipment Manufacturers' Assn., Inc.

R. Thomas Currin, FMC Corp., NC

Edward A. Gadsby, Cyprus Foote Mineral Co., PA

Ron A. Kirsch, Occupational Health Services Inc., TN

Edward S. Krupinski, Sedgwick James of Arizona Inc., AZ

Kevin M. Laporte, Uni-Wash Inc., MI

John E. McConaghie, Reade Mfr. Co., NJ

Neil T. Morgan, Naval Undersea Warfare Engineering Station, WA

Eldon Poulsen, Timet/TDA, NV

Charles F. Reade, Reade Advanced Materials, RI

James A. Robertson, Dow Chemical Co. USA, TX

Peter E. Rogers, Wolcott, VT

Joseph B. Scheller, Silberline Mfr. Co. Inc., PA
Rep. The Aluminum Assn.

Waldemar Seton, SJO Consulting Engineers, OR

John Valiulis, Factory Mutual Research Corp., MA

Alternates

Edward D. Leedy, Industrial Risk Insurers, IL
(Alt. to R. W. Nelson)

Larry J. Moore, Factory Mutual Research Corp., MA
(Alt. to J. Valiulis)

Martha H. Curtis, NFPA Staff Liaison

This list represents the membership at the time the Committee was balloted on the text of this edition. Since that time, changes in the membership may have occurred.

NOTE: Membership on a Committee shall not in and of itself constitute an endorsement of the Association or any document developed by the Committee on which the member serves.

Committee Scope: This Technical Committee shall have primary responsibility for documents on safeguards against fire and explosion in the manufacturing, processing, handling, and storage of combustible metals, powders, and dusts.

NFPA 480
Standard for the
Storage, Handling, and Processing of
Magnesium Solids and Powders

1993 Edition

NOTICE: An asterisk (*) following the number or letter designating a paragraph indicates explanatory material on that paragraph in Appendix A.
Information on referenced publications can be found in Chapter 10 and Appendix D.

Chapter 1 General

1-1 Scope.

1-1.1

This standard shall apply to the storage, handling, and processing of magnesium solids at magnesium foundries, processing plants, and commercial storage facilities.

1-1.2

This standard shall also apply to the storage, handling, processing, and manufacture of magnesium powder.

1-1.3

This standard shall not apply to the primary production of magnesium.

1-1.4*

This standard shall not apply to the transportation of magnesium in any form on public highways, waterways, or by air or rail.

1-1.5

The requirements of NFPA 650, *Standard for Pneumatic Conveying Systems for Handling Combustible Materials*, shall not apply to magnesium.

1-2 Purpose.

The purpose of this standard is to minimize the occurrence of and resulting damage from fire and explosion hazards in the storage, handling, processing, and manufacture of magnesium solids and powders.

1-3 Equivalent Protection.

1-3.1

Existing plants, equipment, structures, and installations that do not comply strictly with the requirements of this standard shall be considered to be in compliance if it can be shown that an equivalent level of protection has been provided or that no specific hazard shall be created or continue to exist through noncompliance.

1-3.2

This standard is not intended to prevent the use of systems, methods, or devices that provide equivalent protection from fire and explosion. NFPA 69, *Standard on Explosion Prevention Systems,* shall be referenced where considering the use of optional systems.

1-4 Definitions.

For the purpose of this standard, the terms below shall be defined as follows.

Approved. Acceptable to the "authority having jurisdiction."

NOTE: The National Fire Protection Association does not approve, inspect or certify any installations, procedures, equipment, or materials nor does it approve or evaluate testing laboratories. In determining the acceptability of installations or procedures, equipment or materials, the authority having jurisdiction may base acceptance on compliance with NFPA or other appropriate standards. In the absence of such standards, said authority may require evidence of proper installation, procedure or use. The authority having jurisdiction may also refer to the listings or labeling practices of an organization concerned with product evaluations which is in a position to determine compliance with appropriate standards for the current production of listed items.

Authority Having Jurisdiction. The "authority having jurisdiction" is the organization, office or individual responsible for "approving" equipment, an installation or a procedure.

NOTE: The phrase "authority having jurisdiction" is used in NFPA documents in a broad manner since jurisdictions and "approval" agencies vary as do their responsibilities. Where public safety is primary, the "authority having jurisdiction" may be a federal, state, local or other regional department or individual such as a fire chief, fire marshal, chief of a fire prevention bureau, labor department, health department, building official, electrical inspector, or others having statutory authority. For insurance purposes, an insurance inspection department, rating bureau, or other insurance company representative may be the "authority having jurisdiction." In many circumstances the property owner or his designated agent assumes the role of the "authority having jurisdiction"; at government installations, the commanding officer or departmental official may be the "authority having jurisdiction."

Fire-Resistive. Meeting the requirements for Type I or Type II construction, as described in NFPA 220, *Standard on Types of Building Construction*.

Heavy Casting. Heavy castings are greater than 25 lb (11.3 kg) and have walls with large cross section weights [at least $^1/_4$ in. (6.4 mm)]. Castings less than 25 lb (11.3 kg) shall be considered light castings.

Labeled. Equipment or materials to which has been attached a label, symbol or other identifying mark of an organization acceptable to the "authority having jurisdiction" and concerned with product evaluation, that maintains periodic inspection of production of labeled equipment or materials and by whose labeling the manufacturer indicates compliance with appropriate standards or performance in a specified manner.

Listed. Equipment or materials included in a list published by an organization acceptable to the "authority having jurisdiction" and concerned with product evaluation, that maintains periodic inspection of production of listed equipment or materials and whose listing states either that the equipment or material meets appropriate standards or has been tested and found suitable for use in a specified manner.

NOTE: The means for identifying listed equipment may vary for each organization concerned with product evaluation, some of which do not recognize equipment as listed unless it is also labeled. The "authority having jurisdiction" should utilize the system employed by the listing organization to identify a listed product.

Magnesium. Refers to either pure metal or alloys having the generally recognized properties of magnesium marketed under different trade names and designations.

Magnesium Powder. Refers to magnesium metal in the form of a chip, granule, flake, or finely divided particle. Any such magnesium metal that is less than $^1/_8$ in. (3.2 mm) in two dimensions or less than 0.05 in. (1.3 mm) in single dimension (e.g., magnesium ribbon) shall be considered a powder.

Magnesium Powder Production Plant. Facilities or buildings whose primary product is bulk magnesium powder. Facilities or buildings in which powder is produced incidental to operations shall not be considered a powder production plant.

Noncombustible. In the form used and under the conditions anticipated, will not ignite, burn, support combustion, or release flammable vapors when subjected to fire or heat. (Materials reported as noncombustible, when tested in accordance with ASTM E136, *Standard Test Method for Behavior of Materials in a Vertical Tube Furnace at 750°C*, shall be considered noncombustible materials.)

Shall. Indicates a mandatory requirement.

Should. Indicates a recommendation or that which is advised but not required.

Swarf. Finely divided metal particles produced by sawing and cutting operations.

Chapter 2 Location and Construction of Magnesium Powder Production Plants

2-1 Location.

2-1.1

Magnesium powder production plants shall be located on a site large enough so that the buildings in which powder is manufactured shall be at least 300 ft (91.5 m) from public roads and from any occupied structure, such as public buildings, dwellings, and business or manufacturing establishments, other than those buildings that are a part of the magnesium powder production plant.

2-1.2

Different production operations shall be located in separate but not adjoining buildings located at least 50 ft (15 m) from each other.

Exception: Two buildings less than 50 ft (15 m) apart shall be permitted if the facing wall of the exposed building shall be capable of resisting a blast pressure of 2.0 psig (13.8 kPa gauge) and shall be nonload-bearing, noncombustible, and without openings.

2-1.3

Separate buildings shall be required where different operations such as but not limited to atomization, grinding, crushing, screening, blending, packaging, or other process are performed.

Exception: More than one operation within the same building shall be permitted if the design provides equivalent protection.

2-2 Security.

2-2.1

This section shall be applied to new and existing facilities. The intent of this section shall be to restrict access to those facilities by the general public and to establish adequate exit facilities for personnel.

2-2.2

The powder production plant shall be surrounded by strong fencing at least 6 ft (1.8 m) high with suitable entrance gates, or otherwise shall be rendered inaccessible.

2-2.3

Security measures taken shall be in accordance with NFPA *101*®, *Life Safety Code*®. (*See 5-9.2.3 of NFPA 101*.)

2-3 Building Construction.

2-3.1

All buildings used for the manufacture, packing, or loading for shipment of magnesium powders shall be single story, without basements, constructed of noncombustible materials throughout, and have nonload-bearing walls. The buildings shall be designed so that all internal surfaces are readily accessible to facilitate cleaning.

Exception: Other construction types shall be permitted if equivalent protection can be demonstrated.

2-3.2

All walls or areas where dust can be produced, which are not of monolithic construction, shall have all masonry joints thoroughly slushed with mortar and troweled smooth so as to leave no interior or exterior voids where magnesium powder can infiltrate and accumulate.

2-3.3

Floors shall be noncombustible hard surface and nonslip, installed with a minimum number of joints in which powder can collect. The requirements of this subsection shall also apply to elevated platforms, balconies, floors, or gratings. (*See Appendix B.*)

2-3.4

Roofs of buildings that house dust-producing operations shall be supported on girders or structural members designed to minimize surfaces on which dust can collect.

2-3.5

Roof decks shall be watertight.

2-4 Doors and Windows.

2-4.1

All exits shall conform with NFPA *101*, *Life Safety Code*.

2-4.2

All doors in fire-rated partitions shall be approved, self-closing fire doors, installed in accordance with NFPA 80, *Standard for Fire Doors and Fire Windows*.

2-4.3*

Windows shall be held in place by friction latches and installed so that they open outward.

2-5* Grounding of Equipment.

All process equipment and all building steel shall be securely grounded by permanent ground wires to prevent accumulation of static electricity.

2-6 Electrical Power.

2-6.1

All electrical equipment and wiring shall be installed in accordance with NFPA 70, *National Electrical Code®*.

2-6.2*

All parts of manufacturing buildings shall be classified.

2-6.3

Buildings shall be provided with emergency lighting systems in accordance with NFPA *101*, *Life Safety Code*. The emergency lighting shall be energized automatically upon loss of electrical power to the buildings.

Exception: Buildings of less than 200 sq ft (19 m^2) not normally occupied shall not be required to have emergency lighting systems.

Chapter 3 Magnesium Mill and Foundry Operations

3-1* Melting and Casting Operations.

3-1.1

Buildings used for the melting and casting of magnesium shall be noncombustible. Melt rooms shall have easy and adequate access to facilitate fire control. Floors around melting operations shall be of hard-burned or vitreous paving block, cast-iron plate, or steel plate, laid in concrete and kept clean and free of moisture.

Exception: Melting and casting shall be permitted in buildings of combustible (Type IV) construction if highly acidic or corrosive conditions are present.

3-1.2

All metal added to melting pots shall be thoroughly dried.

3-1.3

Fuel supply lines to melting pots and preheating installations shall have remote fuel shutoffs and combustion safety controls in accordance with NFPA 86, *Standard for Ovens and Furnaces*, or equivalent.

3-1.4

Furnace settings shall be kept dry and free of iron scale. Safety runoff containers shall be provided for all melting pots and crucibles. Melting pots and crucibles shall be inspected regularly. Pots and crucibles that show evidence of possible failure or that allow molten metal to contact concrete or iron scale shall be discarded.

3-1.5

Ladles, skimmers, and sludge pans shall be thoroughly dried and preheated before contacting molten metal.

3-1.6

Extreme care shall be exercised in pouring magnesium castings to avoid spillage. Permanent molds shall be thoroughly preheated before pouring. Permanent molds shall also be purged with a mixture of sulfur hexafluoride/air/carbon dioxide (SF_6/air/CO_2), argon (Ar), helium (He), or sulfur dioxide gas (SO_2) prior to use and between pourings.

3-1.7

Operators in melting and casting areas shall wear flame-resistant clothing, high foundry shoes, and adequate face protection.

3-2* Heat Treating.

3-2.1

A standard procedure for checking the uniformity of temperatures at various points within heat-treating furnaces shall be established. Furnaces shall be checked prior to use and at regular intervals during use to identify undesirable hot spots.

3-2.2

Furnaces shall be properly and tightly constructed. Gas- or oil-fired furnaces shall be provided with combustion safety controls. (*See NFPA 86, Standard for Ovens and Furnaces*.)

3-2.3

All furnaces shall have two sets of temperature controls operating independently. One shall maintain the desired operating temperature; the other, operating as a high temperature limit control, shall cut off fuel or power to the heat-treating furnace at a temperature slightly above the desired operating temperature.

3-2.4*

Magnesium parts to be put in a heat-treating furnace shall be free of magnesium turnings, chips, and swarf.

3-2.5

Combustible spacers on pallets shall not be used in a heat-treating furnace.

3-2.6

Aluminum parts, sheets, or separators shall not be included in a furnace load of magnesium.

3-2.7

There shall be strict adherence to the heat-treating temperature cycle recommended by the alloy manufacturer.

3-2.8*

Molten salt baths containing nitrates or nitrites shall not be used for heat-treating magnesium alloys.

3-2.9*

Magnesium and aluminum metals shall be segregated and easily identified to avoid the possibility of accidental immersion of magnesium alloys in salt baths used for aluminum.

Chapter 4 Machining and Fabrication of Magnesium

4-1* Machining.

4-1.1

Cutting tools shall not be allowed to ride on the metal without cutting, as frictional heat can ignite any fine metal that is scraped off. For the same reason, the tool shall be backed off as soon as the cut is finished. Cutting tools shall be kept sharp and ground with sufficient rake clearance to minimize rubbing on the end and sides of the tool.

4-1.2*

When drilling deep holes (depth greater than 5 times drill diameter) in magnesium, high-helix drills (45 degrees) shall be used to prevent packing of the chips produced.

4-1.3

Relief on tools used in grooving and parting operations shall be maintained, since the tool tends to rub the sides of the groove as it cuts. Side relief shall be 5 degrees; end relief shall be from 10 degrees to 20 degrees.

4-1.4

If lubrication is needed, as in tapping or extremely fine grooving, a high flash point mineral oil shall be used. Water, water-soluble oils, and oils containing more than 0.2 percent fatty acids shall not be used, as they can generate flammable hydrogen gas.

Exception: Special formulated coolant fluids (water-oil emulsions) that specifically inhibit the formation of hydrogen gas shall be permitted.

4-1.5

Where compressed air is used as a coolant, special precautions shall be taken to keep the air dry.

4-1.6

All machines shall be provided with a pan or tray to catch chips or turnings. The pan or tray shall be installed so that it can be readily withdrawn from the machine in case of fire. It shall be readily accessible for chip removal and for application of extinguishing agent to control a fire.

4-1.6.1 In case of a fire in the chips, the pan or tray shall be immediately withdrawn from the machine, but shall not be picked up or carried away until the fire has been extinguished.

4-2 Dust Collection.

4-2.1

Dust shall be collected by means of suitable hoods or enclosures at each operation. Hoods and enclosures shall be connected either to a dry-type dust collector and blower located outdoors or to a wet-type collector.

4-2.2

Where practical, the dust collection system shall be designed and installed so that the dust is collected upstream of blowers.

4-2.3 Wet Dust Collection.

4-2.3.1 Wet-type collectors shall be permitted to be located indoors.

4-2.3.2 The discharge duct for wet dust collection equipment shall terminate at a safe outside location.

4-2.3.3 The ductwork, dust collector, and fan system shall be designed such that the concentration of magnesium dust in the system is less than 25 percent of the lower flammable limit (LFL) of magnesium.

4-2.3.4 All components of the dust collection system shall be of conductive material.

4-2.3.5 Connecting ducts or suction tubes shall be completely grounded and bonded, with no unnecessary bends. Ducts shall be fabricated and assembled, and shall have a smooth interior and internal lap joints pointing in the direction of airflow. Ducts shall have no unused capped side outlets, pockets, or other dead-end spaces that can allow an accumulation of dust.

4-2.3.6 The power supply to dust-producing machines shall be interlocked with the motor driving the exhaust blower and the liquid-level controller of the liquid precipitation separator in such a way that improper functioning of the dust collection system shall shut down the machine it serves. The interlock system shall function under conditions of belt failure. A time-delay switch or equivalent device shall be provided on the dust-producing machine to prevent starting of its motor drive until the liquid precipitation separator is in complete operation and several air changes have swept out any residual hydrogen.

4-2.4 Liquid Precipitation Collectors.

4-2.4.1* Each dust-producing machine shall be dedicated to the collection of magnesium or magnesium alloy only and have its own dust-separating unit. (*See Figure 4-2.4.2*.)

Exception: With multiunit machines, two dust-producing machines shall be permitted to be served by a single separator. Where multiunit machines are in use, only magnesium shall be processed in each unit.

4-2.4.2 Wet collectors shall be restricted to a dust-loading of no more than 5 gr/cu ft (175 gr/m^3) of inlet air on standard configuration collectors. (*See "Industrial Ventilation: A Manual of Recommended Practice" table on Range of Particle Size, Concentration, and Collector Performance*.)

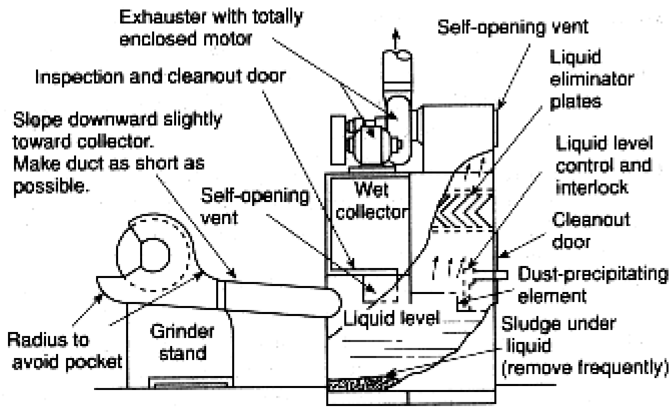


Figure 4-2.4.2 Typical liquid precipitation separation for grinding.

4-2.4.3 Liquid precipitation separators shall be designed such that the hydrogen being generated from the magnesium contacting the water shall be vented at all times.

4-2.4.4 Means of venting to avoid accumulation of hydrogen shall be maintained. Each chamber of the collector shall be vented to dissipate the hydrogen.

4-2.4.5 Sludge level build-up in the sludge tank of the wet collector shall not exceed 5 percent of the tank water capacity as measured by volume. Sludge shall be removed from the collector whenever the collector is to remain inoperative for a period of 24 hours or more.

4-2.4.6 Liquid precipitators shall incorporate the use of positive venting of the sludge tank at all times during shutdown by means of an auxiliary blower that is energized when the main exhaust fan is turned off. The auxiliary fan volume shall not be less than 10 percent of the exhaust fan volume.

4-2.5 Down-Draft Wet Collectors.

4-2.5.1 The number of dust-producing machines shall be limited only by the design of the down-draft bench. All such designed stations shall be individually partitioned from each other. Each down-draft collector shall be used only for the collection of magnesium dust. (*See Figure 4-2.5.1*.)

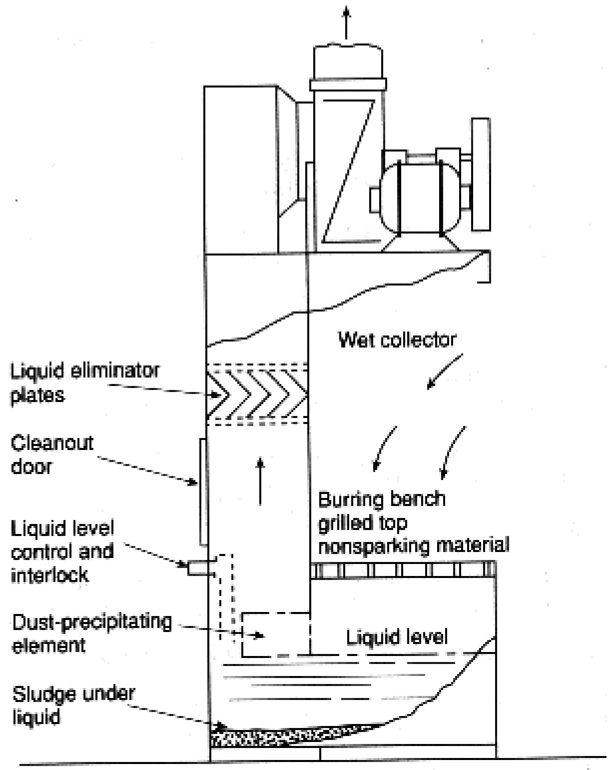


Figure 4-2.5.1 Typical down-draft separator for grinding.

4-2.5.2 The power supply to dust-producing machines shall be interlocked with the motor driving the exhaust blower and the liquid-level controller of the down-draft separator in such a way that improper functioning of the dust collection system will shut down the machine it serves. A time-delay switch or equivalent device shall be provided on the dust-producing machine to prevent starting of its motor drive until the down-draft separator is in complete operation and several air changes have swept out any residual hydrogen.

4-2.5.3 Wet collectors shall be restricted to a dust-loading of no more than 2 gr/cu ft (70 gr/m^3) of inlet air on down-draft bench configuration separators. (*See "Industrial Ventilation: A Manual of Recommended Practice" table on Range of Particle Size, Concentration, and Collector Performance*.)

4-2.5.4 Down-draft bench configuration separators shall maintain no less than 300 ft/min (1.5 m/sec) average work surface capture velocity at each work station. Work surface capture velocity shall be determined as a function of nominal work surface area.

4-2.5.5 Sludge level build-up in the sludge tank of the wet collector shall not exceed 5 percent of the tank water capacity as measured by volume. Sludge shall be removed from the collectors whenever the collector is to remain inoperative for a period of 24 hours or more.

4-2.5.6 Positive venting of the sludge tank shall be maintained at all times by means of an auxiliary blower that is energized when the main exhaust fan is turned off. The auxiliary fan volume shall not be less than 10 percent of the exhaust fan volume.

4-2.5.7 Any chambers that are enclosed shall be vented by natural ventilation.

4-2.6 Dry Dust Collection.

4-2.6.1* Dust shall be collected by means of suitable hoods or enclosures at each operation.

4-2.6.2 Hoods and enclosures shall be connected to a high-efficiency cyclone(s) and blower located outdoors.

4-2.6.3 The cyclone exhaust shall terminate in a safe outside location.

4-2.6.4 All components of a dust collection system shall be made of conductive materials and shall be watertight.

4-2.6.5 The ductwork, cyclone, and fan system shall be designed such that the concentration of magnesium dust in the system is less than 25 percent of the lower flammable limit (LFL).

4-2.6.6 The minimum length of duct from the dust-producing operation(s) to the cyclone shall be 15 ft (4.6 m).

4-2.6.7 The use of media-type collectors shall be prohibited.

4-2.6.8 Explosion venting shall be permitted to be installed on dry-type dust collection systems.

4-2.6.9 Connecting ducts or suction tubes shall be completely grounded and bonded, with no unnecessary bends. Ducts shall be fabricated and assembled, and shall have a smooth interior and internal lap joints pointing in the direction of airflow. Ducts shall have no unused capped side outlets, pockets, or other dead-end spaces that can allow an accumulation of dust.

4-2.6.10 Where practical, the dust collection system shall be designed and installed so that the dust is collected upstream of blowers.

4-2.6.11 Each dust-producing machine shall be equipped with its own dust-separating unit.

Exception: With multiunit machines, two dust-producing machines shall be permitted to be served by a single separator. Where multiunit machines are in use, only magnesium shall be processed in each unit.

4-2.6.12 The power supply to dust-producing machines shall be interlocked with the exhaust blower. The interlock system shall function under conditions of drive belt failure.

4-3 Cleaning.

4-3.1

Systematic cleaning of the entire grinding area, including roof members, pipes, conduits, etc., shall be carried out daily or as often as conditions warrant.

4-3.2

Cleaning shall be done using soft brushes and conductive nonsparking scoops and containers.

4-3.3*

Vacuum cleaners shall not be used unless they are specifically listed for use with magnesium powder or dusts.

4-4 Electrical Equipment.

4-4.1*

Electrical equipment and wiring methods associated with dust-producing machines, including those used in connection with dust collection equipment, shall be approved for Class II, Group E atmospheres and shall be installed in accordance with Article 502 of NFPA 70, *National Electrical Code*.

4-4.2

All electrical equipment shall be inspected and cleaned periodically.

4-4.3

Where flashlights or storage battery-operated lanterns are used, they shall be listed for classified locations.

4-5* Grounding of Equipment.

All equipment shall be securely grounded by permanent ground wires to prevent accumulation of static electricity.

4-6 Safety Precautions.

4-6.1

Operator clothing shall be flame-retardant, easily removable, and shall be kept clean and free from dust. Clothing shall be smooth, allowing dust to be brushed off readily. Clothing shall have no pockets or cuffs. Woolen, silk, or fuzzy outer clothing and shoes with exposed steel parts shall be prohibited.

4-6.2

Machinery and equipment described in Section 5-2 shall not be used for processing other metals until the entire grinder and dust-collecting system are thoroughly cleaned. The grinding wheel or belt shall be replaced prior to work on other metals.

4-6.3

No open flames, electric or gas cutting or welding, or other spark-producing operations shall be permitted in the section of the building where magnesium dust is produced or handled while dust-producing equipment is in operation. Where this type of work is done in such areas, all machinery in the area shall be shut down, and the area shall be thoroughly cleaned to remove all accumulations of magnesium dust. All internal sections of grinding equipment, ducts, and dust collectors shall be completely free of moist or dry magnesium dust, and any hydrogen shall be flushed out.

4-6.4*

Wheels used for grinding magnesium castings shall be relocated for dressing.

Exception: If it is not feasible to move the grinding wheels to a safer location for dressing, the hoods shall be thoroughly cleaned or removed entirely before dressing operations are started, and all deposits of dust on and around the wheel shall be removed before, during, and after dressing.

4-6.5

Nonsparking tools shall be used where making repairs or adjustments around grinding wheels, hoods, or collector units where magnesium dust is present.

4-6.6

Dust collection equipment shall not have filters or other obstructions that will allow accumulation of magnesium dust.

4-7 Drawing, Spinning, and Stamping.

4-7.1

Reliable means to prevent overheating shall be provided where heating magnesium for drawing or spinning.

4-7.2

Clippings and trimmings shall be collected at frequent intervals and placed in clean, dry steel or other noncombustible containers. Fine particles shall be handled according to the requirements of Chapter 5.

Chapter 5 Magnesium Powder — Machinery and Operations

5-1 General Precautions.

5-1.1

In powder handling or manufacturing buildings and in the operation of dust-conveying systems, every precaution shall be taken to avoid the production of sparks from static electricity, electrical faults, friction, or impact (e.g., iron or steel articles on stones, on each other, or on concrete).

5-1.2

Water leakage within or into any building where it can contact magnesium powder shall be prevented to avoid possible spontaneous heating and hydrogen generation.

5-1.3

Electrical heating of any resistance element or load to a high temperature in an area containing a dust hazard shall be prohibited.

5-1.4*

Serious local friction heating of bearings in any machine located in an area containing a dust hazard shall be prevented.

5-2 Requirements for Machinery.

5-2.1

All dust-producing machines and conveyors shall be constructed so that escape of dust is minimized.

5-2.2*

All machinery shall be bonded and grounded to minimize accumulation of static electric charge. This requirement shall be applicable to stamp mortars, mills, fans, and conveyors in all areas where dust is produced or handled. Static conductive belts shall be used on belt-driven equipment.

5-2.3*

Grounded and bonded bearings, properly sealed against dust, shall be used.

5-2.4

Internal machine clearances shall be maintained to prevent internal rubbing or jamming.

5-2.5

High-strength permanent magnetic separators, pneumatic separators, or screens shall be installed ahead of mills, stamps, or pulverizers wherever there is any possibility that tramp metal or other foreign objects can be introduced into the manufacturing operations.

5-3 Start-Up Operations.

All the machine processing contact areas shall be thoroughly cleaned and free from water before being charged with metal and placed into operation.

5-4 Charging and Discharging.

5-4.1

All magnesium powder containers not used for shipping into or out of the plant shall be made of metal.

5-4.2

Where charging magnesium powders to (or discharging from) machines, the containers shall be bonded to the equipment and grounded by a suitable grounding conductor.

5-5 Packaging and Storage.

Magnesium powder shall be stored in steel drums or other closed conductive containers. The containers shall be tightly sealed and stored in a dry location until ready for shipment or repacking.

Chapter 6 In-Plant Conveying of Magnesium Powder

6-1 Containers.

6-1.1

Transfer of powders in-plant shall be done in suitable conductive containers, as described in Chapter 5. Special attention shall be necessary to ensure the magnesium powder is not exposed to moisture.

6-1.2

Containers approved by the U.S. Department of Transportation (DOT) for shipment of magnesium powders shall be used where magnesium powder is transported on pallets by industrial trucks. (*See NFPA 505, Fire Safety Standard for Powered Industrial Trucks Including Type Designations, Areas of Use, Maintenance, and Operation*.)

6-1.3

All wheeled containers, hand trucks, and lift trucks shall be grounded.

6-2 Pneumatic Conveying.

6-2.1

If the conveying gas is air, the magnesium dust-to-air ratio throughout the conveying system shall be held safely below the lower flammable limit (LFL) of the magnesium dust at normal operating conditions. (*See Section 4-2 and Appendix B.*)

6-2.2*

If an inert gas such as argon or helium is used, it shall have an oxygen concentration appropriate to the inerting gas and the particle size of the magnesium dust. Recycling of inert gas shall be permitted. (*See NFPA 69, Standard on Explosion Prevention Systems.*)

6-2.3

The conveying gas shall have a dew point such that no free moisture can condense or accumulate at any point in the system.

6-2.4

A minimum conveying velocity of 3500 ft/min (1068 m/min) shall be maintained throughout the conveying system to prevent the accumulation of dust at any point and to pick up any dust or powder that can drop out during an unscheduled system stoppage. Higher conveying velocities are more desirable and increase safety.

6-3 Ductwork for Conveying Systems.

6-3.1*

Explosion vents, openings protected by antiflashback swing valves, or rupture diaphragms shall be provided on ductwork. Relief shall be to a safe location. The guidelines in NFPA 68, *Guide for Venting of Deflagrations*, do not apply to ductwork for conveying systems for magnesium powder.

6-3.2

Wherever damage to other property or injury to personnel can result from the rupture of the ductwork, and where explosion relief vents cannot provide sufficient pressure relief, the ductwork shall be designed to withstand a sudden internal pressure of 125 psi (862 kPa). (*See NFPA 69, Standard on Explosion Prevention Systems.*)

6-3.2.1 If a portion of the ductwork is so located that no damage to property or injury to personnel can result from its bursting, that portion shall be permitted to be of light construction so as to intentionally fail, thereby acting as an auxiliary explosion vent for the system.

6-3.3

Conveyor ducts shall be fabricated of conductive material. Nonconductive duct liners shall not be used.

6-3.4*

Ducts shall be electrically bonded and grounded to minimize accumulation of static charge.

6-3.5

Where the conveying duct is exposed to weather or moisture, it shall be moisturetight.

6-4 Fan Construction and Arrangement.

6-4.1*

Blades and housings of fans used to move air or inert gas in conveying ducts shall be constructed of conductive material.

6-4.2

Personnel shall not be permitted within 50 ft (15 m) of the fan while it is operating. No maintenance shall be performed on the fan until it is shut down.

Exception: If personnel must approach the fan while it is operating, such as for a pressure test, it shall be done under the direct supervision of a competent technical person and with the knowledge and approval of operating management.

6-4.3

Fans shall be located outside of all manufacturing buildings wherever practical.

6-4.4

Fans shall be electrically interlocked with dust-producing machinery so that the machines shut down if the fan stops.

6-5 Dust Collectors.

6-5.1

High-efficiency cyclone magnesium dust collectors shall be located in and exhausted to a safe outside location, and shall be provided with suitable barricades or other means for protection of personnel and facilities.

6-5.2

Ductwork shall comply with the provisions of Section 6-3.

6-5.3*

The entire dust collection system, including the dust collector, shall be constructed of conductive material and shall be completely bonded and grounded to minimize accumulation of static electric charge.

Chapter 7 Prevention of Dust Accumulations

7-1 General.

7-1.1

Dust shall not be permitted to accumulate. Spills shall be removed at once, using conductive, nonsparking scoops and soft brooms or brushes having natural fiber bristles. Compressed-air blowdown shall not be permitted.

7-1.2

The use of water for cleaning shall not be allowed in manufacturing areas unless the following requirements are met.

(a) It has been determined by competent technical personnel that the use of high-pressure water will be the safest and most effective method of cleaning.

(b) Operating management has full knowledge of and has granted approval for its use.

(c) Adequate ventilation, either natural or forced, is available to maintain the hydrogen concentrations safely below the lower flammable limit (LFL).

(d) Complete drainage of all water and powder to a safe, remote area is available.

(e) The area has been cleaned to remove all loose accumulations of powder.

7-2 Cleaning Frequency.

7-2.1*

Operating personnel and supervisors shall exercise great care to prevent the accumulation of excessive dust on any portions of buildings or machinery not regularly cleaned during daily operations.

7-2.2

Regular periodic cleaning, with all machinery idle and power off, shall be performed as frequently as conditions warrant.

Chapter 8 Storage of Magnesium Solids

8-1* Storage of Pigs, Ingots, and Billets.

8-1.1

The size of piles shall be limited. Minimum aisle widths shall be based on the height of the pile as per 8-1.2.4. The pile height shall not exceed 20 ft (6.1 m).

8-1.2 Yard (Outdoor) Storage.

8-1.2.1 Magnesium ingots shall be carefully piled on firm and generally level areas to prevent tilting or toppling. Storage areas and yard pavements shall be well drained. The storage area shall be kept free of grass, weeds, and accumulations of combustible materials.

8-1.2.2 Combustible flooring or supports shall not be used under piles of ingots.

8-1.2.3 The quantity of magnesium stored in any pile shall be kept to a minimum. In no case shall the amount exceed 1,000,000 lb (453,600 kg).

8-1.2.4 Aisle widths shall be not less than one-half the height of the piles, but in no case shall they be less than 10 ft (3 m).

8-1.2.5 Readily combustible material shall not be stored within a distance of 25 ft (7.6 m) from any pile of magnesium ingots.

8-1.2.6 An open space, equal to the height of the piles plus 10 ft (3 m), shall be provided between the stored magnesium ingots and adjoining property lines where combustible material or buildings are exposed or where the adjacent occupancy can provide fire exposure to the magnesium.

8-1.2.7 No cutting, welding, or burning shall be permitted without operating management approval.

8-1.3 Indoor Storage.

8-1.3.1 Storage shall be in buildings of noncombustible construction.

Exception: Other construction types shall be permitted if equivalent protection can be demonstrated.

8-1.3.2* Floors shall be of noncombustible construction and shall be well drained to prevent accumulations of water in puddles.

8-1.3.3 Supports used under piles of magnesium ingots shall be noncombustible. There shall be no idle pallet storage.

8-1.3.4 The quantity of magnesium ingots stored in any one pile shall be kept to a minimum, but in no case shall the amount exceed 500,000 lb (226,800 kg).

8-1.3.5 Aisle widths shall comply with 8-1.2.4.

8-2* Storage of Heavy Castings.

8-2.1

Buildings used for the storage of heavy magnesium castings shall be of noncombustible construction.

Exception: Storage shall be permitted in buildings of combustible construction if the buildings are fully protected by an automatic sprinkler system.

8-2.2*

Floors shall be of noncombustible construction and shall be well drained to prevent accumulations of water in puddles.

8-2.3

All magnesium castings shall be inspected prior to storage to see that they are clean and free of chips or fine particles of magnesium.

8-2.4

The size of storage piles of heavy magnesium castings, either in cartons or crates or free of any packing material, shall be limited to 1250 cu ft (36 m^3). Aisles shall be maintained to permit inspection and effective use of fire protection equipment.

8-2.5

Aisle widths shall be not less than one-half the height of the piles.

8-2.6*

Automatic sprinkler protection shall be permitted to be installed in magnesium storage buildings where combustible cartons, crates, or other packing materials are present.

8-3 Storage of Light Castings.

8-3.1

Light magnesium castings shall be stored in noncombustible buildings and shall be segregated from other storage.

Exception: Storage of light castings shall be permitted in buildings of combustible construction *if the buildings are fully protected by an automatic sprinkler system. (See 8-3.4.)*

8-3.2

Piles of stored light magnesium castings, either in cartons or crates or without packing, shall be limited in size to 1000 cu ft (28 m^3). Light castings shall be segregated from other combustible materials and kept away from flames or sources of heat capable of causing ignition.

8-3.3

Aisle widths shall not be less than one-half the height of the piles.

8-3.4*

Automatic sprinkler protection shall be permitted to be installed in magnesium storage buildings where combustible cartons, crates, or packing materials are present.

8-4 Storage in Mills, Warehouses, and Processing Plants.

8-4.1

Buildings shall be of noncombustible construction.

Exception: Storage shall be permitted in buildings of combustible construction if the buildings are fully protected by an automatic sprinkler system.

8-4.2

Magnesium shall not be stored in or over a basement or similar subgrade space.

8-4.3

Stocks of magnesium shall be stored separately from other combustible materials.

8-4.4*

Automatic sprinkler protection shall be permitted to be installed in magnesium storage buildings where combustible cartons, crates, or packing materials are present.

8-5 Storage in Racks or Bins.

8-5.1

Racks shall be permitted to be extended along walls in optional lengths. Aisle spaces in front of racks shall be equal to the height of the racks. All aisle spaces shall be kept clear.

8-5.2

Combustible rubbish, spare crates, and separators shall not be permitted to accumulate within the rack space. Separators and metal sheets shall not be stacked on edge, and leaned against racks, as they will prevent heat from a small fire from activating automatic sprinklers and act as shields against sprinkler discharge.

8-6 Storage of Scrap Magnesium.

8-6.1

This section shall apply to the storage of scrap magnesium in the form of chips, turnings, swarf, or other fine particles.

8-6.2

Buildings shall be of noncombustible construction.

Exception: Other construction types shall be permitted if equivalent protection can be demonstrated.

8-6.3

Dry magnesium scraps shall be kept well separated from other combustible materials. Scraps shall be kept in covered steel or other noncombustible containers and shall be kept in such manner or locations that they will not become wet. Outside storage of magnesium fines shall be permitted if such storage is separated from buildings or personnel and great care is exercised to avoid the fines from becoming wet.

8-6.4*

Wet magnesium scrap (chips, fines, swarf, or sludge) shall be kept under water in a covered and vented steel container in an outside location. Sources of ignition shall be kept away from the drum vent and top. Containers shall not be stacked.

8-6.5*

Storage in quantities greater than 50 cu ft (1.4 m^3) (six 55-gal drums) shall be kept separate from other occupancies by fire-resistive construction without window openings or by an open space of at least 50 ft (15 m). Such buildings shall have explosion vents.

8-6.6

The use of automatic sprinklers in scrap magnesium storage buildings or areas shall be prohibited.

8-6.7

Suitable fire extinguishment materials shall be readily available in these locations.

8-7* Storage of Solid Magnesium Scrap.

8-7.1

Solid magnesium scrap, such as clippings and castings, shall be stored in noncombustible bins or containers pending salvage.

8-7.2

Oily rags, packing materials, and similar combustibles shall not be permitted in storage bins or areas storing solid magnesium scrap.

8-7.3*

Solid scrap shall be treated in accordance with Section 8-6 or 8-7.

8-8 Storage of Magnesium Powder.

8-8.1

Buildings used to store magnesium powder shall be of noncombustible single-story construction.

8-8.2

The use of automatic sprinklers in such buildings shall be strictly prohibited.

8-8.3

Magnesium powder shall be kept well separated from other combustible or reactive metals.

8-8.4

Magnesium powder shall be stored in steel drums or other closed containers. The containers shall be kept tightly sealed and stored in dry locations.

8-8.5

As necessary, magnesium powder storage areas shall be checked for water leakage.

8-8.6

Areas that routinely are used for the storage of magnesium powder shall be considered Class II, Group E, in accordance with NFPA 70, *National Electrical Code*.

8-8.7

Suitable fire extinguishment material shall be readily available in these locations.

8-8.8

Where magnesium powder in drums is stacked for storage, the maximum height shall not exceed 18 ft (5.5 m). Stacked storage shall be done in such a manner so as to ensure stability. Under no circumstances shall containers be permitted to topple over. The safest manner of storage is achieved using no stacking.

8-9 Storage of Finished Products.

8-9.1

This section shall apply to the storage of magnesium, in warehouses, wholesale facilities, and retail outlets, in the form of finished parts in which magnesium makes up the major portion of the articles on a volumetric basis.

8-9.2

Storage in quantities greater than 50 cu ft (1.4 m^3) shall be separated from storage of other materials that are either combustible or in combustible containers by aisles with a minimum width equal to the height of the piles of magnesium products.

8-9.3

Magnesium products stored in quantities greater than 1000 cu ft (28 m^3) shall be separated into piles each not larger than 1000 cu ft (28 m^3), with the minimum aisle width equal to the height of the piles.

8-9.4 *

Where storage in quantities greater than 1000 cu ft (28 m^3) is contained in a building of combustible construction, or the magnesium products are packed in combustible crates or cartons, or there is other combustible storage within 30 ft (9 m) of the magnesium, the storage area shall be protected by automatic sprinklers.

Chapter 9 Fire Fighting Procedures

9-1 General Precautions.

9-1.1

Magnesium is a flammable solid that once ignited shall be best extinguished by smothering (i.e., excluding oxygen). Burning magnesium responds poorly to several types of extinguishing agents used for other types of materials. Use of inappropriate agents can result in accelerating the fire or in causing an explosion (due to hydrogen). Under no circumstances shall the use of water, halogenated agents (halon), carbon dioxide, foam, or nitrogen be permitted.

Exception: A few individual burning chips of magnesium shall be permitted to be extinguished by dropping them into a bucket of water.

9-1.2

Magnesium solids and heavy magnesium castings normally do not ignite until reaching the melting point of magnesium. Extreme caution shall be taken to avoid molten magnesium contacting water, as an explosion will occur.

9-1.3*

The use of pressurized extinguishing agents shall not be permitted on a magnesium powder or chip fire, unless applied carefully so as not to disturb or spread the magnesium powder. This shall be performed only by trained personnel. This is due to the danger of spreading the burning powder or chips or creating a dust cloud. The bulk dry extinguishing agents shall be provided in areas where chips and powders are produced or used. The bulk dry extinguishing agents shall be kept dry (i.e., free of moisture). Application of wet extinguishing agents accelerates a magnesium fire and could result in an explosion.

9-1.4

The use of automatic sprinklers shall not be permitted in areas where molten magnesium is produced or handled, in areas where heat-treating furnaces are located, or in areas where magnesium chips or powders are produced or handled.

9-2 Reignition Conditions.

Extreme care shall be exercised even after a magnesium fire appears to be out. Reignition can occur due to high temperatures of the magnesium beneath the extinguishing agent, especially if the magnesium or the extinguishing agent covering the magnesium is disturbed. This allows air to reignite the magnesium.

9-3 Automatic Sprinkler Protection.

Automatic sprinkler protection shall only be permitted in storage areas for heavy or light magnesium castings in accordance with Sections 8-2, 8-3, and A-8-7.

9-4 Emergency Procedures.

Employees shall be instructed and trained in fighting magnesium fires using the permissible techniques appropriate for the various physical forms of magnesium. Employees shall be instructed in emergency procedures to be followed in the event of a fire.

9-5 Fire Fighting Organization.

Any fire fighting organizations that respond to an emergency shall be trained in the hazards involved in fighting a magnesium fire.

9-6 Employee Instruction.

9-6.1

All employees shall be carefully and thoroughly instructed by their supervisors regarding the hazards of their working environment and their behavior and procedures in case of fire or explosion.

9-6.2

All employees shall be shown the location of electrical switches and alarms, first-aid equipment, safety equipment, and fire extinguishing equipment.

9-6.3

The hazards posed by causing dust clouds and the danger of applying liquids onto an incipient fire shall be explained.

9-6.4

Strict discipline and scrupulous housekeeping shall be maintained at all times.

9-6.5

Attention shall be given to employee training and organizational planning to ensure safe and proper evacuation of the area.

9-7 Periodic Inspection.

9-7.1

A thorough systematic inspection shall be made at regular intervals not to exceed 1 month.

9-7.2

At least two or more competent persons shall conduct each inspection, and their findings and recommendations shall be permanently recorded in the plant's principal office.

9-7.3

The inspection shall include the following:

(a) General safety precautions

(b) Fire fighting equipment

(c) First-aid equipment

(d) Housekeeping

(e) Electrical and mechanical equipment

(f) Procedures.

9-7.4

Indicating and recording instruments and alarm devices shall be checked daily and the results recorded. Instruments shall be calibrated every 6 months.

Chapter 10 Referenced Publications

10-1

The following documents or portions thereof are referenced within this document and shall be considered part of the requirements of this document. The edition indicated for each reference is the current edition as of the date of the NFPA issuance of this document.

10-1.1 NFPA Publications.

National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.

NFPA 69, *Standard on Explosion Prevention Systems*, 1992 edition.

NFPA 70, *National Electrical Code*, 1993 edition.

NFPA 80, *Standard for Fire Doors and Fire Windows*, 1992 edition.

NFPA 86, *Standard for Ovens and Furnaces*, 1990 edition.

NFPA *101*, *Life Safety Code*, 1991 edition.

NFPA 220, *Standard on Types of Building Construction*, 1992 edition.

NFPA 505, *Fire Safety Standard for Powered Industrial Trucks Including Type Designations, Areas of Use, Maintenance, and Operation*, 1992 edition.

NFPA 650, *Standard for Pneumatic Conveying Systems for Handling Combustible Materials*, 1990 edition.

10-1.2 ASTM Publication.

American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103.

ASTM E136, *Standard Test Method for Behavior of Materials in a Vertical Tube Furnace at 750°C*, 1992 edition.

Appendix A Explanatory Material

This Appendix is not a part of the requirements of this NFPA document, but is included for information purposes only.

A-1-1.4 Transportation Regulations.

Regulations for the domestic shipment of dangerous goods (magnesium powder is so classified) are issued by the U.S. Department of Transportation (49 CFR, Parts 100-199), which has specific responsibility for promulgating the regulations. These regulations are updated and published yearly by the DOT. International shipments are regulated by the United Nations, International Air Transport Association, International Maritime Organization, and other national agencies. Attention is directed to activity now underway to consolidate the regulations under auspices of the United Nations.

A-2-4.3

See NFPA 68, *Guide for Venting of Deflagrations*.

A-2-5

See NFPA 77, *Recommended Practice on Static Electricity*.

A-2-6.2

See NFPA 497B, *Recommended Practice for the Classification of Class II Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas*.

A-3-1

Chips, turnings, powders, or swarf that is being preheated or charged to melting pots will autoignite at temperatures below that of the solid metal. Solids should be free of these smaller particles, as they can ignite and, in turn, ignite the solids. There should be no depression directly beneath the magnesium storage area where water can accumulate or flow during a fire.

A-3-2

Extreme care should be taken when heat treating aluminum containing magnesium alloys since aluminum additions form a eutectic alloy with considerably lower melting and autoignition temperatures. Failure to identify the alloy can result in heat-treating furnace fires.

A-3-2.4

To further retard ignition of magnesium, mixtures of sulfur dioxide (SO_2), sulfur hexafluoride with carbon dioxide (SF_6/CO_2), helium (He), and argon (Ar) with air is recommended in heat-treating furnaces operating above 750°F (399°C).

A-3-2.8

Special salt fluxes can be safely used for dip-brazing of magnesium.

A-3-2.9

Magnesium and aluminum form a eutectic alloy with considerably lower melting temperatures and autoignition temperatures than either parent metal.

A-4-1

Flashing of chips during machining should be minimized by any of the following methods:

(a) Keep surface speed below 300 ft/min (1.5 m/sec) or above 2200 ft/min (11 m/sec).

(b) Increase feed rate from 0.0008 in. to 0.010 in. (0.02 mm to 0.25 mm) per revolution.

(c) Control relative humidity in the machining area to 45 percent or lower at 70°F (21°C) room temperature.

(d) Apply a coolant.

A-4-1.2

Use of high-helix drills prevents frictional heat and possible flash fires in fines. High-helix drills are also recommended for drilling deep holes through composite or sandwich sections.

A-4-2.4.1 Interaction between magnesium and aluminum alloy fines (if the aluminum contains more than $^1/_2$ to 1 percent copper) in wet collector sludge can lead to hydrogen evolution and heat generation greatly exceeding that produced by magnesium fines alone. See NFPA 65, *Standard for the Processing and Finishing of Aluminum*.

A-4-2.6.1 The maximum concentration of less than 100 mesh magnesium dust should never exceed 0.03 oz per cu ft (0.03 g/L) (air), which is the lower flammable limit (LFL).

Minimum explosive concentrations for magnesium dust in air are published in RI 6516, “Explosibility of Metal Powders.” Although the metal dust-air suspension normally can be held below the lower flammable limit (LFL) in the conveying system, the suspension can pass through the flammable range in the collector at the end of the system.

A-4-3.3

Standard commercial industrial vacuum cleaners should not be used, as they are not safe for use with magnesium.

A-4-4.1

See NFPA 497B, *Recommended Practice for the Classification of Class II Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas*, for guidance on classified areas for Class II materials.

A-4-5

See NFPA 77, *Recommended Practice on Static Electricity*.

A-4-6.4

Special precautions are necessary to prevent ignitions while dressing the wheels used for grinding magnesium castings. Hot metal thrown off by the dressing tool can ignite dust or magnesium deposits in the hood or duct.

A-5-1.4

Temperature-sensing elements connected to alarms or machine stop switches can be employed for locations where overheating of bearings or other elements may be anticipated.

A-5-2.2

See NFPA 77, *Recommended Practice on Static Electricity*.

A-5-2.3

Bearings located outside of the volume containing magnesium dust are preferred. Bearings within the volume containing magnesium dust are potential sources of ignition in the event of a failure. Bearings should be located outside the volume containing magnesium dust.

A-6-2.2

Completely inert gas cannot be used as an inerting medium, since the magnesium powder would eventually, at some point in the process, be exposed to the atmosphere, at which time the unreacted surfaces would be oxidized; enough heat would be produced to initiate either a fire or an explosion. To provide maximum safety, a means for the controlled oxidation of newly exposed surfaces is provided by regulating the oxygen concentration in the inert gas. The mixture serves to control the rate of oxidation, while materially reducing the fire and explosion hazard.

A-6-3.1

See NFPA 68, *Guide for Venting of Deflagrations*.

A-6-3.4

See NFPA 77, *Recommended Practice on Static Electricity*.

A-6-4.1

Wherever practical, the design should not allow the transported dust or powder to pass through the fan before entering the final collector. Where practical, fans should be located outside of all manufacturing buildings.

A-6-5.3

See NFPA 77, *Recommended Practice on Static Electricity*.

A-7-2.1

See NFPA 497B, *Recommended Practice for the Classification of Class II Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas*.

A-8-1

Industrial buildings or separate storage areas in which magnesium parts are being stored in quantities greater than 500 lb (227 kg), or where these magnesium parts are the primary hazard, should be labeled in accordance with NFPA 704, *Standard System for the Identification of the Fire Hazards of Materials*. This serves as a warning to fire fighters of the potential risk in the event of an emergency.

A-8-1.3.2 Storage of magnesium ingots should be on the first or ground floor. Basements or depressions below the magnesium storage area into which water or molten metal can flow should be avoided.

A-8-2

Fines that come in contact with water, water-soluble oils, and oils containing more than 0.2 percent fatty acids can generate flammable hydrogen gas. Fines that come in contact with animal or vegetable oils may ignite spontaneously.

A-8-2.2

Storage of magnesium castings should be on the first or ground floor. Basements or depressions below the magnesium cast storage area into which water or molten metal can flow should be avoided.

A-8-2.6

Sprinkler systems are of vital importance in heavy magnesium casting areas that also contain significant amounts of ordinary combustibles, as sprinkler operation can prevent the magnesium from becoming involved in the fire.

A-8-3.4

A slow-burning fire in nearby combustible material can develop enough heat to ignite thin-section magnesium, producing a well-involved magnesium fire before automatic sprinklers operate. Special importance, therefore, should be attached to prompt fire detection and alarm service, design of a fast-operating automatic sprinkler system, and avoidance of obstructions to sprinkler discharge. See NFPA 13, *Standard for the Installation of Sprinkler Systems*.

A-8-4.4

A slow-burning fire in nearby combustible material can develop enough heat to ignite thin-section magnesium, producing a well-involved magnesium fire before automatic sprinklers operate. Special importance, therefore, should be attached to prompt fire detection and alarm service, design of a fast-operating automatic sprinkler system, and avoidance of obstructions to sprinkler discharge. See NFPA 13, *Standard for the Installation of Sprinkler Systems*.

A-8-6.4

The wet magnesium should be checked frequently to ensure that it remains totally immersed during storage.

A-8-6.5

For design information, see NFPA 68, *Guide for Venting of Deflagrations*.

A-8-7

The danger of ignition of this solid scrap is very low, provided it is not stored with combustible materials. However, automatic sprinkler protection is recommended.

A-8-7.3

Scrap magnesium is usually received by secondary smelters in truck or carload quantities. Solid scrap may be shipped loose, but chips and turnings are packed in covered steel drums. Since storage is in the open, incipient fires can be readily detected and extinguished.

A-8-9.4

A slow-burning fire in nearby combustible material can develop enough heat to ignite thin-section magnesium, producing a well-involved magnesium fire before automatic sprinklers operate. Special importance, therefore, should be attached to prompt fire detection and alarm service, design of a fast-operating automatic sprinkler system, and avoidance of obstructions to sprinkler discharge. See NFPA 13, *Standard for the Installation of Sprinkler Systems*.

A-9-1.3

Recommended extinguishing agents for magnesium are approved Class D agents, gases (SO_2, SF_6/CO_2, Ar, He), and nonreactive granular material or powders. In cases involving molten magnesium burning, dry magnesium foundry flux can be used as an extinguishing agent. The flux melts or crusts over the hot metal, excluding air from the burning metal. Magnesium foundry flux has been shown to be an effective extinguishing agent. Protective gas mixtures are useful only if the magnesium vessel is closed.

Appendix B Supplementary Information on Magnesium

This Appendix is not a part of the requirements of this NFPA document, but is included for information purposes only.

B-1 Properties.

Magnesium, a silvery white metal with an atomic weight of 24.32 and specific gravity of 1.74, is one of the lightest known structural metals. The melting point of magnesium is 1202°F (650°C). The ignition temperature is generally considered to be close to the melting point, but ignition of magnesium in certain forms can occur at temperatures below the melting point. Magnesium ribbon, fine magnesium shavings, and magnesium powders can be ignited under certain conditions at temperatures of about 950°F (510°C), and a very finely divided magnesium powder has been ignited at temperatures below 900°F (482°C).

Commercially pure magnesium contains traces of aluminum, copper, iron, manganese, nickel, and silicon, but these contaminants in typical analyses generally total less than 0.2 percent. Metal marketed under different trade names and commonly referred to as magnesium might be one of a large number of different alloys containing different percentages of magnesium, aluminum, zinc, and manganese. Some of these alloys can have ignition temperatures considerably lower than that determined for pure magnesium. In some cases, the melting point of certain alloys can be as low as 800°F (427°C) and can ignite if held at this lower temperature for some time.

B-2 Radioactive Alloys.

A few magnesium alloys are produced that contain thorium. Thorium, which is a low-level radioactive material, is used in these alloys up to a nominal concentration of 3 percent.

The natural decay or "daughter" products of thorium are locked in the alloy until such time as the metal is melted, burned, or chemically disintegrated. Under fire conditions, these decay products exist within visible fumes and are diluted as the visible fumes dissipate. These elements can be inhaled with possible irradiation of lung tissue and deposition in bone structure. Maximum permissible airborne concentrations of such radioactive materials have been established by the Nuclear Regulatory Commission and are based on continuous exposure for a normal 40-hour work week.

B-3 Spot Tests for Magnesium.

In the construction or assembly of certain machinery or equipment, magnesium or one of its alloys having similar properties might be used for a few of the component parts, and where finished or painted products are being stored or handled it can be difficult to determine the percentage of magnesium. Investigation has shown that silver nitrate or acetic acid (vinegar) can be used to distinguish between parts composed of magnesium and those composed of aluminum. The portion of metal to be tested is first cleaned of grease, dirt, oxide, etc., using sandpaper or steel wool. After the test area has been prepared, a drop of acetic acid is placed on it. If hydrogen bubbles develop, the piece tested is magnesium.

B-3.1 Silver Nitrate Test.

The test solution is prepared by dissolving about 5 g of silver nitrate ($AgNO_3$) in 1 L of distilled water. The application of this solution immediately produces a black coloration on magnesium or magnesium alloy. (This coloration is essentially reduced silver.) No coloration is noted on aluminum and its alloys, or most other metals. Zinc and cadmium exhibit a similar black coloration but are much heavier.

B-4 Combustibility and Explosibility.

The ignitability potential of magnesium depends to a large extent upon the size and shape of the material as well as the size and intensity of the source of ignition. Where magnesium exists in the form of ribbon, shavings, or chips with thin, feather-like edges, or as grinding dust, a spark can be sufficient to start the material burning. Heavier pieces such as ingots and thick wall castings are difficult to ignite because heat is conducted away rapidly from the source of ignition. If the entire piece of metal is raised to the ignition temperature [about 1200°F (649°C) for pure magnesium and many of the alloys], self-sustained burning will occur.

The combustibility of magnesium, the ineffectiveness of ordinary types of extinguishing agents on magnesium fires, and the fact that, under certain conditions, the application of some of these agents intensifies burning and can release hydrogen to form an explosive gas-air mixture, all combine to create serious fire and explosion hazards.

Magnesium, in its solid form, melts as it burns and can form puddles of molten magnesium that, in the presence of sufficient moisture, can pose explosion hazards similar to those associated with other molten metals.

B-5 General.

B-5.1

Electrically conductive flooring is often employed in magnesium powder plants, although it is recognized that it is difficult to maintain the conductivity of the floor over a period of time using currently available materials.

B-5.2

The surface of a conductive floor provides a path of moderate electrical conductivity between all persons and portable equipment making contact with the floor, thus preventing the accumulation of dangerous electrostatic charges.

B-5.3

The maximum resistance of a conductive floor is usually less than 1,000,000 ohms, as measured between two electrodes placed 3 ft (0.3 m) apart at any two points on the floor. The minimum resistance is usually greater than 25,000 ohms, as measured between a ground connection and an electrode placed at any location on the floor. This minimum resistance value provides protection for personnel against electrical shocks. Resistance values should be checked at regular intervals.

B-6 Testing for Minimum and Maximum Resistance.

The following equipment and procedures are accepted practice.

B-6.1

Each electrode weighs 5 lb (2.2 kg) and has a dry, flat, circular contact area 2.5 in. (63.5 mm) in diameter. The electrode consists of a surface of aluminum foil 0.0005 in. to 0.001 in. (0.013 mm to 0.025 mm) thick, backed by a layer of rubber 0.25 in. (6.4 mm) thick, and measuring 40 to 60 durometer hardness, as determined by a shore-type durometer or equivalent. (*See ASTM D2240, Standard Test Method for Rubber Property — Durometer Hardness*.)

B-6.2

Resistance should be measured with a suitably calibrated ohmmeter that can operate on a nominal open circuit output voltage of 500 volts dc and a short-circuit current of 2.5 milliamperes to 10 milliamperes.

B-6.3

Measurements should be made at five or more locations in each room and the results averaged.

B-6.4

To comply with the maximum resistance limit, the average of all measurements should be less than 1,000,000 ohms.

B-6.5

To comply with the minimum resistance limit, no individual measurement should be less than 10,000 ohms, and the average of not fewer than five measurements should be greater than 25,000 ohms.

B-6.6

Where resistance to ground is measured, two measurements are customarily made at each location, with the test leads interchanged at the instruments between the two measurements. The average of the two measurements is taken as the resistance to ground at that location. Measurements are customarily taken with the electrode or electrodes more than 3 ft (0.9 m) from any ground connection or grounded object resting on the floor.[1]

[1]If resistance changes appreciably over time during a measurement, the value observed after the voltage has been applied for about 5 minutes should be considered the measured value.

B-7 Building Construction.

While noncombustible construction is preferred for buildings occupied by magnesium melting and processing operations, limited-combustible and combustible construction can be permitted in appropriate circumstances.

B-7.1

Moisture and foreign material are dangerous where molten metal is present. Such moisture can result from outdoor storage or from collection of condensate during indoor storage.

B-7.2

Flash fires in fine dust can result in serious injury. While the chance of a flash fire igniting castings is remote, a fire in accumulated dust can be intense enough to cause ignition of castings.

B-7.3

Fire can occur in furnaces or ovens where magnesium is being heat-treated if there is lack of proper temperature control or if the surface of the metal is not free of dust or fine particles of metal. Failure to provide for proper circulation of the heated air in the furnace can result in overheating or higher temperatures in certain zones than those indicated by the thermocouples that operate the temperature control devices.

B-7.3.1 Direct contact between aluminum and magnesium at heat-treating temperatures promotes diffusion and alloying of one metal with the other, resulting in the formation of low-melting, ignitable alloys.

B-7.3.2 Certain commonly used mixtures of molten nitrates and nitrites can react explosively with the magnesium alloys immersed in them.

B-8

Machining magnesium includes sawing, turning, chipping, drilling, routing, reaming, tapping, milling, and shaping. Magnesium can usually be machined at the maximum speeds obtainable on modern machine tools. The low power required allows heavy depths of cut and high rates of feed, which are consistent with good workmanship. The resulting chips are thick and relatively massive; they seldom ignite due to their relatively large heat capacity.

B-9

Magnesium pigs, ingots, and billets are not easily ignited, but they burn if exposed to fire of sufficient intensity.

B-9.1

Heavy castings [25 lb (11.3 kg) or greater] having walls with large cross sections [at least $^1/_4$ in. (6.4 mm)] can be ignited after some delay where in contact with burning magnesium chips or where exposed to fires in ordinary combustible materials.

B-10

Prime (commercially pure) magnesium chips and fines are commonly used in Grignard and other chemical reactions. These chips are generally free of contaminants and are not subject to spontaneous ignition. Where such chips are produced, shipped, and stored for chemical and metallurgical process purposes, the conditions of handling and storage are such that a fire is unlikely.

While water should not be applied to a large chip fire, automatic sprinklers are valuable in confining or extinguishing an incipient fire in packaging and in small amounts of chips, provided detection and discharge are rapid.

B-11

While the flame temperature of burning magnesium is about 7200°F (3983°C), the heat of combustion is only about half that of common petroleum products. Thus, fire fighting personnel can approach a fire closely during extinguishment, if care is exercised.

B-11.1

Fires in magnesium should be extinguished using a Class D extinguishing agent or a dry inert granular material.

B-11.2

Magnesium fires are more easily extinguished if attacked with the proper extinguishing agents during the early stages of the fire. Certain extinguishing agents accelerate a magnesium fire. These agents include foam, carbon dioxide, halogenated agents, and dry chemical agents containing mono- or diammonium phosphate. Also, the use of water on a magnesium chip or powder fire should be avoided. It is very difficult to extinguish a massive fire in magnesium powder. The major problem involves control of fires in the incipient stage.

The fire area should not be re-entered until all combustion has stopped and the material has cooled to ambient temperature.

B-11.3

Reignition can occur due to high localized heat or spontaneous heating. To avoid reignition, the residual material should be immediately smothered.

B-11.4

It is recommended that a practice fire drill be conducted once each year to familiarize local fire department personnel with the proper method of fighting Class D fires.

B-12

Provisions should be made to automatically cut off electrical power and lighting circuits in manufacturing buildings when one or more safety-sensing devices are activated by high pressure, low airflow, abnormal oxygen content, excessive vibration, or other pertinent factors that are being monitored. Alternatively, these sensing devices should be arranged to sound an alarm in those locations where prompt corrective action can be taken.

B-13

Temperature-sensing elements connected to alarms or machine stop switches should be employed for locations where overheating of bearings or other elements might be anticipated.

B-14

Open bin storage is not desirable. Storage bins for powders should be sealed and purged with inert gas prior to filling.

Appendix C Explosibility of Magnesium Dust

This Appendix is not a part of the requirements of this NFPA document, but is included for information purposes only.

Definition.

Deflagration: An explosion in which the rate of propagation of the flame front into the unreacted medium occurs at less than sonic speed. If the shock wave propagates at a rate greater than the speed of sound, it becomes a detonation.

C-1 Explosions in Magnesium/Air Dust Mixtures.

Magnesium dust is a potentially hazardous material when suspended in air. The finer the dust particle size, the more easily it disperses, the longer it takes to settle, and the easier it is to ignite.

In order for a magnesium/air dust cloud to experience a deflagration (explosion), two conditions are necessary:

(a) An ignitable concentration of dust in air;

(b) An ignition source of sufficient strength to ignite the combustible air/dust mixture.

Research conducted by the U.S. Bureau of Mines and others over many years has established values for these parameters. In using these data for the design of industrial equipment and systems, it should be kept in mind that other factors such as metal purity, particle size distribution, moisture, ambient pressure and temperature, and turbulence all affect the exact conditions for initiating explosions in such dust clouds.

A summary of the best available information for unalloyed magnesium dust in air is listed in Table C-1. Attention is directed to the fact that the data shown are for 200 mesh (less than 74 microns) in small unvented containers. These conditions are not truly representative of magnesium powder manufacture but provide useful guidelines for avoiding accidents. For this reason, an additional safety factor should be used where applying this information to industrial-scale operations. A safety factor of 2-3 is suggested.

Table C-1 Explosion Characteristics of Unalloyed Magnesium Dust in Air [200 Mesh (74 microns)]

Explosibility Index*	10
Ignition Sensitivity†	3.0
Explosion Severity††	7.4
Maximum Explosion Pressure (psig)	115

	(793 kPa gauge)
Maximum Rate of Pressure Rise (psi/sec)	15,000 (103,410 kPa/sec)
Ignition Temperature Cloud (°C)	560°C
Minimum Cloud Ignition Energy	
Joules (watt-seconds)	0.04
Minimum Explosion Concentration (oz/cu ft)	0.03
Limiting Oxygen % for Spark Ignition	-§
(K_{St} values for specific particle sizes)	

* Explosibility Index = ignition sensitivity × explosion severity

† Ignition Sensitivity =

$$\frac{\text{[Ignition temp} \times \text{min energy} \times \text{min conc. (LEL)] Pittsburgh coal dust}}{\text{[Ignition temp} \times \text{min energy} \times \text{min conc.] Sample dust}}$$

†† Explosion Severity =

$$\frac{\text{[Max exp. pressure} \times \text{max rate of pressure rise] Pittsburgh coal dust}}{\text{[Max exp. pressure} \times \text{max rate of pressure rise] Sample dust}}$$

§Burns in carbon dioxide, nitrogen, and halons.

Magnesium dust explosions are characterized by very rapid rates of pressure rise to a maximum pressure of approximately 115 psig (793 kPa gauge). Limited industrial loss experience indicates the use of venting and explosion suppression techniques can be impractical for large-size vessels. As a consequence, the avoidance of conditions that can lead to explosions is of particular importance with fine magnesium powders.

It has been determined that the presence of some coarse particles, greater than 100 mesh (150 microns) in size, in magnesium dust has little effect on the initiation of explosions in such dust clouds. For this reason, the particle size distribution of the powders in air systems should be known, and equipment designs and safe operating procedures should be based on the expected concentration of less than 100 mesh (less than 149 microns) powder in these systems. In the absence of this information, the total amount of powder should be used. While this can limit production rates, it provides an additional factor of safety where dealing with undocumented powders.

From a practical standpoint, a combination of explosion containment with other techniques might be the only other way to avoid personal injury and property damage in manufacturing operations unless oxygen reduction by dilution with argon or helium is employed. This containment technique, together with the avoidance of conditions that can lead to dust explosions, represents the best way of avoiding catastrophic accidents in magnesium dust handling equipment and systems.

Dust clouds can be ignited by flames, arcs, high-temperature surfaces, and static and friction sparks, etc. The destructive effect of magnesium dust explosions can be greater than that of some vapor and gas explosions because of the comparatively high rate at which the pressure rises in some dust explosions. This results in longer impulse-loading on personnel and structures than that resulting from a gas explosion and is the factor that causes a dust explosion to be more destructive. Attention is directed to the fact that a 0.5 psig (3.5 kPa gauge) overpressure will cause an 8-in. (20-cm) concrete block wall to fail. It is obvious that this overpressure is reached extremely rapidly where the rate pressure rise is 15,000 psi/sec (103,410 kPa/sec) and the maximum pressure reached is 115 psig (793 kPa gauge).

In pneumatic conveying systems, proper selection of fan or blower capacity can be used to maintain a powder concentration below the LFL of 0.03 oz/cu ft (0.03 g/L) shown in Table C-1. If the quantity of powder to be transported is predetermined, the fan can be selected to provide enough conveying air to keep the dust concentration below the ignitable level. Care should be taken, however, to maintain sufficient superficial air velocity [over 3500 ft/sec (1068 m/min)] in the duct system to avoid saltation in horizontal lines and drop-out in vertical lines.

While the complete design of a "safe" system is beyond the scope of this appendix, a simplified example serves to illustrate the above point. For instance, to transport 10 lb/min (4.5 kg/min) of fine [less than 100 mesh (less than 149 microns)] magnesium powder introduced uniformly into an air-conveying system while maintaining a dust concentration below the 0.03 oz/cu ft (0.03 g/L) flammability level, the airflow is calculated as follows:

$$\text{Air Needed} = \frac{10\ \text{lb/min} \times 16\ \text{oz}}{0.03\ \text{oz/cu ft}} = 5333.3\ \text{CFM}$$

For a 14-in. diameter round duct, the superficial air velocity from the following equation is 4994 ft/min, neglecting density effects.

$$Q = AV$$

where Q = quantity of airflow

A = cross-sectional area

V = velocity

$$Q = \frac{5333.3}{1.068} = 4994 \text{ ft/min}$$

NOTE: These calculations do not take into account the effects of temperature, altitude, and humidity on the airflow. The result indicates that to maintain a nonignitable dust concentration, the amount of air needed per pound of powder $\left[\frac{(5333.3 \text{ CFM})}{10 \text{ lb}} \times 0.075 = 40 \text{ lb}\right]$ is quite large.

The standard density of dry air is taken at 0.075 lb/cu ft.

Therefore, highly diluted phase-conveying is necessary for safe operation. With the added recommended safety factor of 2 to 3, this ratio becomes much greater. Observing these guidelines provides a simple starting point for the design of a reasonably safe system for air-conveying fine magnesium powder.

In air-separating cyclones, the dust concentration can be assumed to approximate the concentration in the conveying lines less an allowance of 10 percent for air-lock leakage, etc. Nearly all of the conveying air entering a cyclone leaves through the vent, and there are no semistagnant air spaces except for the small volumes of the dust trap and dip-leg.[1] As a consequence, the concentration of magnesium fines [less than 100 mesh (less than 149 microns)] in the air in a properly designed cyclone separator does not exceed the lower flammability limit in such units where the recommended safety factor and other considerations referred to previously are used as guidelines.

[1]Attention is directed to the difference between this situation and a grain silo, where a large amount of dust is discharged by gravity from the separator into semistagnant air in a large cylindrical tank or silo, which allows the dust concentration to materially increase.

With regard to the presence of ignition sources of sufficient strength to ignite a dust cloud, if the lower flammability level of 0.03 oz/cu ft (0.03 g/L) is exceeded, it should be noted that the 40 millijoules (MJ) energy required to ignite such a dust cloud is nearly 20 to 50 times greater than that required to ignite flammable gas or vapor mixtures. Such strong ignition sources do not generally exist in magnesium powder plants that operate with lightning protection and electrically bonded and grounded equipment to minimize static electricity, and that have strong magnetic separators to remove tramp metals from process streams, where all the above safety equipment and arrangements are regularly inspected and maintained.

C-2 Chemical Process to Render Magnesium Fines Noncombustible.

Metallic magnesium fines generated in the production of structural magnesium parts or other products often have no commercial value and can present a fire hazard. They should be disposed of regularly. These fines might be the wet fines from a dust collector system, partially converted to an inactive state by having been collected in water, or chips from a machining operation.

Chips and turnings may be wet, dry, or oil-soaked, and, frequently, they are contaminated. Fines vary in size from the dust generated in a sanding or buffing operation to a much larger particle produced by sawing, drilling, or turning. Prior to disposing of any fines, a secondary processor/melter should be contacted to assess the recycled value of the by-product.

In seeking a means of disposal for magnesium fines, other than by burning, the most obvious solution is to immerse them in water. Magnesium fines can be rendered partially inactive by reacting them with water to form hydrogen and noncombustible magnesium hydroxide. Film formation on the magnesium, however, normally slows the process beyond practical limits; however, once substantially reduced to magnesium hydroxide, the residual sludge does not burn and can be disposed of like any other inert material. It has been found that partially inactivated magnesium fines containing approximately 10 percent metallic magnesium do not burn.

Magnesium sludge can more effectively be rendered chemically inactive and noncombustible by reacting it with a 5 percent solution of ferrous chloride ($FeCl_2•2H_2O$). The reaction takes place with the evolution of hydrogen at such a rate that the magnesium fines are changed in less than 24 hours to a concentration of magnesium hydroxide that the residue cannot burn. Since hydrogen is generated by the reaction, the process should be carried out in an open container placed outside in a location where natural air movement will prevent the accumulation of explosive concentrations of hydrogen in air. Open flames and smoking should be prohibited in the immediate vicinity of the process. The amount of $FeCl_2•2H_2O$ commonly employed in the decomposition is approximately 0.6 lb (0.3 kg) for each pound of magnesium fines (dry weight). The amount of water in the fines should be considered in determining the weight of the magnesium fines. Exact concentrations should be determined on the basis of the type of fines being handled. The cycle can be repeated easily in the same container until the amount of brown, damp residue is such that the container should be cleaned out. To be certain of complete reaction, a sample of the residue should be heated with a Bunsen burner or oxyacetylene torch to determine if it can be ignited. While the method is simple, it should be operated under strict technical supervision to avoid disposal of partially reacted magnesium.

The main constituent of the residual sludge is magnesium hydroxide [$Mg(OH)_2$], which indicates that the iron salt functions not as a reagent that is consumed in the reaction, but rather as a catalyst that simply promotes the reaction with water to form magnesium hydroxide and hydrogen gas. Considerable heat is generated in the early stages of the reaction, especially if the particles are finely divided and clean. During this stage, considerable hydrogen is released and foaming can occur. Small amounts of hydrogen continue to evolve until no metallic magnesium is present.

It should be remembered that this is a chemical reaction and the results obtained depend on several factors. It has been mentioned that freshly formed, finely divided particles react quite quickly, so that considerable heat, hydrogen evolution, and foaming can occur. In case of excessive foaming, the reaction should be slowed down, or a defoamer can be added. If the fines have been under water in a collector system for some time, less metallic magnesium is present, and the reaction is slower. Particles coated with oil or tar pose special problems, and the use of a detergent might be advisable. If the reaction is carried out in a container that has little surface area and limited excess water, the heat of reaction might be sufficient to ignite the hydrogen. Hydrogen is less liable to be trapped in a shallow container, and a larger surface area provides better heat dissipation.

It is recommended that the details of the process be worked out by technically competent personnel. The daily operation can be performed on a routine basis under technical supervision. If excessive heating is a problem, more water can be added. It has been found that a weaker solution will frequently render the material noncombustible in the desired length of time with less initial heating. The reaction vessel can be mild steel. In one case, a tank constructed of $^1/_4$-in. (6.4-mm) thick mild steel, in almost constant use, lasted 10 years before leaking.

Ferric chloride ($FeCl_3$) in dilute amounts can be used in place of ferrous chloride ($FeCl_2$) to produce the same results. The initial rate of reaction is faster when using ferric chloride; however, this can be controlled by adding more water or initially adding the magnesium fines slowly. Solutions of $FeCl_3$ in water as low as 1 percent dilute have been used to render certain types of magnesium fines noncombustible within 24 hours.

$FeCl_3$ is available in crystalline form ($FeCl_3•6H_2O$) or the anhydrous form (98 percent $FeCl_3$). Either can be used, but the anhydrous form should be handled like an acid because of the hazard posed by chemical burns to the skin and eyes. In figuring the required amounts of either $FeCl_2$ or $FeCl_3$, the water produced by crystallization should be considered in determining the strength of the solution.

Several companies have used either $FeCl_2$ or $FeCl_3$ to render magnesium fines noncombustible. The general experience supports the original work done on a laboratory scale. The following two examples provide information of interest.

Case 1

Material Treated: Fines from wire brushing sheet collected in a wet dust collector or fine shavings from a milling operation.

Tank Size: 8 ft (2.4 m) wide × 20 ft (6.1 m) long × 27 in. (69 cm) deep.

Amount of Fines Treated: Amount of fines in water solution varies considerably from batch to batch. Several hundred pounds have been treated at a time.

Amount of Chemical Added: 25 lb (11.4 kg) of $FeCl_2•6H_2O$ or 15 lb (6.8 kg) of anhydrous $FeCl_3$ (98 percent $FeCl_3$) per 100 gal (379 l) of liquid in the tank. $FeCl_2•2H_2O$ is added as a powder; $FeCl_3•6H_2O$ is added in cake form; the 98 percent $FeCl_3$ is a powder and is made up as a water solution and pumped into the tank.

Result: Little heat evolution, low foaming, and a noncombustible sludge within 24 hours.

NOTE: The reaction is carried on outside, and a steam coil is used to warm the solution in the winter. The residue is checked with a propane torch to determine combustibility. Adequate protection from chemical burns is provided where using anhydrous $FeCl_3$ (98 percent).

Case 2

Material Treated: Fines generated by sanding of magnesium die castings that have been collected in a wet dust collector.

Tank Size: 5 ft (1.5 m) wide × 8 ft (2.4 m) long × $3^1/_2$ ft (1 m) deep (steel dumpster box).

Amount of Fines Treated: Approximately 60 lb (27 kg) magnesium fines in a 55-gal (208-l) drum filled with fines and water. To this is added approximately 92 gal (348 l) of water that results in a liquid depth of 5 in. (12.7 cm) in the tank.

Amount of Chemical Used: 44 lb (20 kg) of 98 percent $FeCl_3$ added with an aluminum hand scoop.

Result: Some heat evolution, foaming, and a noncombustible sludge within 24 hours.

NOTE: If too much ferric chloride is used at once, the reaction is quite violent. Where 100 lb (45.4 kg) of magnesium fines were treated, the foam overflowed the tank. Each lot is tested for combustibility with a propane torch. The operator is protected against chemical burns while adding the $FeCl_3$ to the solution.

The following generalizations taken from the experience of users provides further information of interest.

(a) The magnesium fines can be added to the solution or the solution added to the fines. Additional fines can be added to a previous batch containing inactivated sludge. Experience indicates the time needed to complete each reaction and the amount of either $FeCl_2$ or $FeCl_3$ that needs to be added with each increment of fines.

(b) The ratio of $FeCl_2$ or $FeCl_3$ to magnesium content is subject to alteration based on a number of conditions, but the reaction takes place over a broad range of concentrations. The amount required should be determined for the fines being treated and the time allowed for reaction. The recommendation is to use 0.6 lb (0.3 kg) of $FeCl_2$•$2H_2O$ for each pound of magnesium fines (dry weight). The upper limit on concentration used has been 5 percent, but in many cases a lower concentration has been satisfactory and has produced less initial heat and foaming.

(c) Personnel handling anhydrous ferric chloride or ferric chloride solutions should wear overalls, rubber aprons, rubber gloves, and chemical goggles.

(d) Moist fines should not be flushed through long lines because they can build up a layer of semimoist material in the pipe. Inert sludge does not create a fire hazard under these same conditions.

(e) Heating with a steam line has been used to speed up the reaction process, especially in winter and after the initial rapid reaction stage is over.

(f) Foaming can be decreased by the use of defoaming agents. A greater quantity of water limits the heating and slows down the formation of foam.

(g) Longer reaction times might be needed to inactivate larger particles or those that are covered with oil or tars.

(h) For the purpose of estimating metal content, a cu ft (m^3) of material taken from a wet dust collector should be assumed to contain approximately 30 lb (13.6 kg) of metallic dust and 6 gal

(23 L) of water. Approximate weights used for dry fines are 50 lb per cu ft (800 kg/m^3) of sawdust and 15 lb per cu ft (240 kg/m^3) of rotary filings.

(i) Particular care should be taken in adding the initial $^1/_4$ lb to $^1/_2$ lb (0.11 kg to 0.22 kg) of magnesium fines per pound of $FeCl_2$ or $FeCl_3$ content of the solution. During this period, the reaction rate can be very rapid with fine powders (60 to 80 percent completion in 5 minutes), due to the initial acidity of the iron chloride salts. Beyond this point, however, the reaction rate moderates to a stable 4 to 5 percent of completion every 5 minutes (50 to 60 percent per hour).

(j) If magnesium and aluminum fines are mixed, the magnesium still reacts with the ferrous chloride or ferric chloride solution.

(k) Partially deactivated fines containing 10 percent metallic magnesium do not support combustion.

(l) After reaction is complete, the inert residue should be disposed of as waste or fill material.

Although this method has been widely used in the past, current environmental regulations should be met; therefore, a review with local authorities should be conducted to ensure compliance with all local, state, and federal requirements.

Appendix D Referenced Publications

D-1

The following documents or portions thereof are referenced within this document for informational purposes only and thus are not considered part of the requirements of this document. The edition indicated for each reference is the current edition as of the date of the NFPA issuance of this document.

D-1.1 NFPA Publications.

National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.

NFPA 13, *Standard for the Installation of Sprinkler Systems*, 1991 edition.

NFPA 65, *Standard for the Processing and Finishing of Aluminum*, 1993 edition.

NFPA 68, *Guide for Venting of Deflagrations*, 1988 edition.

NFPA 77, *Recommended Practice on Static Electricity*, 1993 edition.

NFPA 497B, *Recommended Practice for the Classification of Class II Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas*, 1991 edition.

NFPA 704, *Standard System for the Identification of the Fire Hazards of Materials*, 1990 edition.

D-1.2 Other Publications.

D-1.2.1 ASTM Publication. American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103-1187.

ASTM D2240, *Standard Test Method for Rubber Property — Durometer Hardness*, 1991 edition.

D-1.2.2 U.S. Bureau of Mines Publication. U.S. Bureau of Mines, Cochrans Mill Road, Pittsburgh, PA 15236-0070.

RI 6516, "Explosibility of Metal Powders," M. Jacobson, A.R. Cooper, and J. Nagy, 1964.

D-1.2.3 U.S. Government Publication. Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402.

49 CFR, *Code of Federal Regulations*, Parts 100-199.

D-1.2.4 Additional Publications.

Bartknecht, W., "Explosions Pressure Relief," Chemical Engineering Progress, 11th Loss Prevention Symposium, Houston, 1977.

Bartknecht, W., *Exploseonen*, 1979 Springer-Verlog Berlin, Heildeberg, NY.

Bartknecht, W., "Report on Investigations on the Problem of Pressure Relief of Explosions of Combustible Dusts in Vessels," Staub Reinhalt, Luft, Vol. 34, No. 11, Nov. 1974, and Vol. 34, No. 12, Dec. 1974.

Bodurtha, F.T., *Industrial Explosion, Prevention and Protection*, McGraw Hill, New York, 1980.

"Combustible Dusts," Loss Prevention Data Sheet 7-76, 1976, Factory Mutual Research Corp., Norwood, MA.

Donat, C., "Pressure Relief as Used in Explosion Protection," Chemical Engineering Progress, 11th Loss Prevention Symposium, Houston, 1977.

Fire Protection Handbook, 17th ed., National Fire Protection Association, Quincy, MA, 1991.

"Industrial Ventilation: A Manual of Recommended Practice," 21st ed., Lansing, MI, American Conference of Governmental Industrial Hygienists, 1991.

Palmer, K.N., Dust Explosions and Fires, Chapman & Hall, London, 1973.

NFPA 481

1995 Edition

Standard for the Production, Processing, Handling, and Storage of Titanium

1995 Edition

This edition of NFPA 481, *Standard for the Production, Processing, Handling, and Storage of Titanium*, was prepared by the Technical Committee on Combustible Metals and Metal Dusts and acted on by the National Fire Protection Association, Inc., at its Annual Meeting held May 22-25, 1995, in Denver, CO. It was issued by the Standards Council on July 21, 1995, with an effective date of August 11, 1995, and supersedes all previous editions.

This edition of NFPA 481 was approved as an American National Standard on August 11, 1995.

Origin and Development of NFPA 481

This standard was initiated in 1955, tentatively adopted in 1957 and, with certain amendments, was adopted by the National Fire Protection Association in May, 1958. Amendments were adopted in 1959 and 1961.

A complete revision of the 1961 edition was adopted in 1972. Amendments to the 1972 edition were adopted in 1974.

In 1980, the 1974 edition was completely revised primarily to comply with the NFPA Manual of Style. Minor technical corrections were also made at this time. The completely revised edition was adopted by the Association at its 1981 Fall Meeting, and the revision was designated the 1982 edition.

The 1987 edition was a reconfirmation of the 1982 edition.

For this 1995 edition, the Committee has completely revised the standard to update the fire and dust explosion prevention measures and the requirements for safe handling of titanium solids and powders. The Committee revision has also incorporated editorial and style revisions to comply with the NFPA Manual of Style and to assist in making the document more usable, adoptable, and enforceable.

Technical Committee on Combustible Metals and Metal Dusts

Robert W. Nelson, *Chair*
Industrial Risk Insurers, CT
Rep. Industrial Risk Insurers

Roy E. Adams, TIMET, NV
Rep. Titanium Development Assn.

Tom Christman, Martin Marietta Energy Systems, TN

R. Thomas Currin, Salisbury, NC

Ralph W. Hawk, Cyprus Foote Mineral Co., NC

Ron A. Kirsch, Occupational Health Services Inc., TN

Edward S. Krupinski, Marsh & McLennan, Inc., AZ

Kevin M. Laporte, Uni-Wash Inc., MI

John E. McConaghie, Reade Mfg. Co., NJ

Neil T. Morgan, Naval Undersea Warfare Engineering Station, WA

David L. Oberholtzer, Valimet, Inc., CA
Rep. The Aluminum Assn.

James A. Robertson, Dow Chemical Co. U.S.A., TX

Peter E. Rogers, Wolcott, VT

Waldemar Seton, SJO Consulting Engr., OR

John Valiulis, Factory Mutual Research Corp., MA

Alternates

Edward D. Leedy, Industrial Risk Insurers, IL
(Alt. to R. W. Nelson)

W. Anthony Major, Silberline Mfg., Co., Inc., PA
(Alt. to D. L. Oberholtzer)

Larry J. Moore, Factory Mutual Research, MA
(Alt. to J. Valiulis)

Nonvoting

Albert Muller, Lebanon, NJ
(Member Emeritus)

Martha H. Curtis, NFPA Staff Liaison

This list represents the membership at the time the Committee was balloted on the text of this edition. Since that time, changes in the membership may have occurred.

NOTE: Membership on a Committee shall not in and of itself constitute an endorsement of the Association or any document developed by the Committee on which the member serves.

Committee Scope: This Committee shall have primary responsibility for documents on safeguards against fire and explosion in the manufacturing, processing, handling, and storage of combustible metals, powders, and dusts.

NFPA 481
Standard for the
Production, Processing, Handling, and Storage of Titanium

1995 Edition

NOTICE: An asterisk (*) following the number or letter designating a paragraph indicates explanatory material on that paragraph in Appendix A.
Information on referenced publications can be found in Chapter 9 and Appendix C.

Chapter 1 General

1-1 Scope.

1-1.1

This standard shall apply to the production, processing, handling, and storage of titanium.

1-1.2

This standard shall also apply to finished parts and those materials, including scrap, that exhibit the burning characteristics of titanium.

1-1.3

This standard shall not apply to the transportation of titanium in any form on public highways and waterways, or by air or rail.

1-1.4

This standard shall not apply to those laboratories handling hazardous chemicals as defined in NFPA 45, *Standard on Fire Protection for Laboratories Using Chemicals*.

1-2* Purpose.

The purpose of this standard shall be to provide requirements addressing the fire and explosion hazards of titanium and titanium alloys and to outline requirements for fire prevention and protection.

1-3 Equivalency.

Nothing in this standard shall be intended to prevent the use of systems, methods, or devices of equivalent or superior quality, strength, fire resistance, effectiveness, durability, and safety over those prescribed by this standard, provided technical documentation is made available to the authority having jurisdiction to demonstrate equivalency and the system, method, or device is approved for the intended purpose.

1-4 Applicability.

The provisions of this document shall be considered necessary to provide a reasonable level of protection from loss of life and property from fire and explosion. They reflect situations and the state-of-the-art prevalent at the time the standard was issued. Unless otherwise noted, it shall not be intended that the provisions of this document be applied to facilities, equipment, structures, or installations that were existing or approved for construction or installation prior to the effective date of the document, except in those cases where it is determined by the authority having jurisdiction that the existing situation involves a distinct hazard to life or adjacent property.

1-5 Definitions.

For the purpose of this standard, the following terms shall have the meanings given below.

Approved.* Acceptable to the authority having jurisdiction.

Authority Having Jurisdiction.* The organization, office, or individual responsible for approving equipment, an installation, or a procedure.

Labeled. Equipment or materials to which has been attached a label, symbol, or other identifying mark of an organization that is acceptable to the authority having jurisdiction and concerned with product evaluation that maintains periodic inspection of production of labeled equipment or materials and by whose labeling the manufacturer indicates compliance with appropriate standards or performance in a specified manner.

Listed.* Equipment or materials included in a list published by an organization acceptable to the authority having jurisdiction and concerned with product evaluation that maintains periodic inspection of production of listed equipment or materials and whose listing states either that the equipment or material meets appropriate standards or has been tested and found suitable for use in a specified manner.

Media Collector. Refers to either a bag house or a filter-type cartridge collector used for collecting dust.

Shall. Indicates a mandatory requirement.

Should. Indicates a recommendation or that which is advised but not required.

Titanium. Refers to either pure metal or alloys having the generally recognized properties of titanium metal, including the fire or explosion characteristics of titanium in its various forms.

Titanium Chips.* Particles produced from a cutting, machining, or grinding operation that are not oxidized and that are not diluted by noncombustible materials.

Titanium Dust.* Any finely divided titanium material 420 microns or smaller in diameter (material passing U.S. No. 40 Standard Sieve) that presents a fire or explosion hazard when dispersed and ignited in air.

Titanium Fines. Titanium particles typically 20 mesh and below that can be ignited in a static layer.

Titanium Powder.* See Titanium Dust and Titanium Fines.

Titanium Sponge.* Titanium metal after it has been won from the ore but before it is melted into ingot.

Titanium Swarf. Particles produced from a cutting, machining, or grinding operation that causes partial oxidation of the parent material or dilution by other inert materials.

Chapter 2 Sponge Production

2-1 Plant Construction.

2-1.1*

Buildings housing reduction furnaces, boring and crushing facilities, and magnesium refining operations shall be constructed of noncombustible materials. Consideration shall be given to the provision of explosion venting in accordance with current accepted practices.

2-1.2

Building exits shall comply with NFPA *101®*, *Life Safety Code®*.

2-1.3*

Floors in reduction, boring, and crushing buildings shall be made of noncombustible materials, such as concrete, brick, or steel plates.

2-1.4

Magnesium refining and casting operations shall be protected from rain, and all possibilities of water spillage shall be avoided.

2-2 Processing Equipment.

2-2.1

Reactor vessels shall be air-cooled.

Exception: Magnesium reduction-sealed vessels shall be permitted to be water-cooled and designed to prevent water from entering the reaction vessel.

2-2.2

Furnaces shall be kept dry and free of iron scale and metal spillage.

2-2.3

Fuel supply lines to gas-fired furnaces shall have an emergency shutoff valve located within easy access outside of the building that contains the reduction furnaces.

NOTE: For information on emergency gas shutoff valves, see NFPA 54, *National Fuel Gas Code*.

2-2.4

All electrically operated or controlled processing equipment shall be installed in accordance with NFPA 70, *National Electrical Code®*.

2-3 Storage of Raw Materials.

2-3.1

Magnesium ingots for use in the Kroll process shall be stored in accordance with NFPA 480, *Standard for the Storage, Handling, and Processing of Magnesium Solids and Powders*.

2-3.2*

Chlorine shall be handled and stored in accordance with accepted industry practice.

2-3.3*

Bulk containers of liquid titanium tetrachloride ($TiCl_4$) shall be stored in a well-ventilated place located away from areas of acute fire hazard. Containers shall be plainly identified and tightly sealed until used.

2-4 Dust Collection.

2-4.1

Dust resulting from the crushing of titanium sponge shall be safely managed to minimize the risk of fires and explosions.

2-4.2

Media collectors shall not be used for the collection of titanium sponge fines.

2-4.3

Dry collectors shall be emptied before or when 80 percent of the storage capacity of the collector is attained. The maximum volume of titanium fines collected before emptying shall not exceed 5 gal (19 L).

2-4.4*

Dust collectors for Kroll-distilled material shall be located outside buildings and shall be provided with explosion vents.

2-4.5*

Fans that handle combustible dust and air mixtures shall be constructed of nonsparking materials and shall be constructed in accordance with NFPA 91, *Standard for Exhaust Systems for Air Conveying of Materials*.

2-5* Personnel Safety Precautions.

Personnel involved in reduction furnace tapping, removal of molten magnesium chloride, and magnesium refining and casting shall wear tight-fitting, above-the-ankle shoes, flame-retardant clothing, heat-resistant gloves, and face shields.

2-6 Sponge Storage.

2-6.1

Titanium sponge shall be stored in closed metal containers with a maximum capacity that are capable of being moved by available equipment.

2-6.2

Titanium storage areas shall be kept free of combustible materials, well-ventilated, equipped with required fire protection equipment, and plainly marked with No Smoking signs.

2-6.3

Where drums are used, storage shall be limited to one-drum tiers per pallet, and no more than four pallet loads high. Stacked storage shall be positioned in such a manner as to ensure stability.

2-6.4

Aisles shall be provided for maneuverability of material-handling equipment, accessibility, and to facilitate fire-fighting operations.

Chapter 3* Titanium Melting

3-1 Explosion Prevention.

3-1.1

The water supply to crucibles shall be monitored continuously by a system that automatically interrupts power to the furnace upon a drop in water pressure or flow. In addition, an emergency source of cooling water shall be provided and shall be actuated automatically by flow interlock in the event of interruption of the primary cooling water.

3-1.2

The use of a magnetic field to deflect the electric arc away from the crucible wall shall be considered.

3-1.3

Water-cooled furnaces shall be located in a protective concrete vault, or the crucible and its water jacket shall be isolated to protect personnel and to minimize damage if an explosion occurs.

3-1.4*

The upper chamber of the furnace shall be provided with a pressure-relieving device, such as a rupture disc, to aid in safely relieving pressure if water enters the furnace. Means shall be provided to prevent influx of air through the pressure-relief port. The release pressure of the rupture disc shall be 20 psig (138 kPa gauge) maximum. Large low-pressure ports shall not be used.

3-1.5

A clearance shall be maintained at all times between the electrode and the crucible wall to minimize arcing to the crucible wall.

3-1.6

The furnace shall be equipped with a device that continuously senses pressure within the furnace. The device shall automatically interrupt power to the melting heat source in the event of an expected sudden rise in pressure.

3-1.7

The furnace shall be equipped with:

(a) Water flow, temperature, and pressure sensors on all cooling systems;

(b) Arc voltage and melting power recorders;

(c) Electrode position indicators;

(d) Furnace pressure sensors and recorders; and

(e) Set point alarms on all systems to warn of abnormal conditions.

3-2* Casting.

3-2.1*

The water supply to crucibles shall be monitored continuously by a system that automatically interrupts power to the melting heat source upon a drop in water pressure or flow. In addition, an emergency source of cooling water shall be provided and shall be actuated automatically by flow interlock in the event of interruption of the primary cooling water.

3-2.2

Molds for titanium casting shall be made of material that is compatible with molten titanium. Molds shall be dried thoroughly and stored carefully to prevent accumulation of moisture in the molds.

3-2.3

The casting chamber shall be cooled or shall be sufficiently massive, or both, to accommodate a spill, since mold breaks are inevitable.

3-2.4

Control consoles for water-cooled melting and casting operations shall be located remote from melting areas and outside of furnace vaults.

3-2.5*

Residue from casting furnaces shall be placed in steel boxes and moved outside the building.

Chapter 4* Mill Operations

4-1 Fire Prevention.

4-1.1

Tanks in which flammable or combustible solvents are used for degreasing shall comply with NFPA 30, *Flammable and Combustible Liquids Code*.

4-1.2*

Sawing, grinding, and cutting equipment shall be grounded.

4-1.3

All titanium chips shall be collected in closed-top metal containers and removed daily, as a minimum, to a safe storage or disposal area.

4-1.4

Forge presses, heavy grinders, and other milling equipment operated by hydraulic systems shall use a less hazardous hydraulic oil with a flash point greater than 200°F (93°C) if oil leaks are anticipated.

4-1.5

Nonflammable coolants shall be used for wet grinding, cutting, or sawing operations. The coolant shall be filtered on a continuous basis and the collected solids shall not be permitted to accumulate in quantities greater than 5 gal (19 L) and shall be moved to a safe storage or disposal area.

4-1.6

Flammable and combustible liquids coatings applied to ingots or billets shall meet the requirements of NFPA 34, *Standard for Dipping and Coating Processes Using Flammable or Combustible Liquids*.

4-1.7

Oily crushed lathe turnings, raw turnings, and swarf shall be collected in closed-top metal containers and removed daily, as a minimum, to a safe storage or disposal area.

4-1.8

Furnaces or other heating equipment used for heating titanium shall be free of iron scale or residue that could react exothermically with the metal being heated.

Chapter 5 Machining and Fabrication

5-1* Machining Operations.

Cutting tools shall be of proper design and shall be kept sharp for satisfactory work with titanium.

5-2 Welding.

5-2.1

All welding of titanium shall be carried out under an inert atmosphere, such as helium, argon, or under vacuum.

5-2.2

Electric arc or gas torch welding shall not be permitted in any room where titanium powder is produced, handled, packaged, or stored until all powder has been removed and all equipment washed thoroughly.

5-3 Titanium Dust Collection.

5-3.1

Titanium dust shall be collected by means of hoods or enclosures at each dust-producing operation. The hoods or enclosures shall be connected to liquid precipitation separators, and the suction unit shall be installed so that the dust is converted to sludge without contact, in the dry state, with any high-speed moving parts. [*See Figures A-5-3.1(a) through (e).*]

5-3.2

Connecting ducts or suction tubes between points of collection and separators shall be completely bonded and grounded. Ducts and tubes shall be as short as possible, with no unnecessary bends. Ducts shall be fabricated and installed in accordance with NFPA 91, *Standard for Exhaust Systems for Air Conveying of Materials*.

5-3.3

Titanium dust-producing equipment shall be connected to dust-separating equipment. Multiple pieces of titanium dust-producing equipment shall be permitted to be connected to a single titanium dust-separating unit. An evaluation shall be made to determine if multiple pieces of dust-producing equipment can be safely served by a single dust-separating unit.

5-3.4*

If the titanium dust-separating unit is to be used for other materials, it shall be thoroughly cleaned of all incompatible materials prior to and after its use.

5-3.5

The power supply to the dust-producing equipment shall be interlocked with the airflow from the exhaust blower and the liquid level controller of the separator so that improper functioning of the dust collection system will shut down the equipment it serves. A time delay switch or equivalent device shall be provided on the dust-producing equipment to prevent starting of its motor drive until the separator is in complete operation.

5-3.6 Housekeeping.

5-3.6.1 Systematic cleaning of the entire building containing dust-producing equipment, including roof members, pipes, conduits, etc., shall be conducted as conditions warrant. Cleaning methods shall be limited to those methods that minimize the probability of having a fire or explosion, as determined by a person knowledgeable in the properties of titanium dust.

5-3.6.2 Due to the inherent hazards associated with the use of fixed vacuum-cleaning systems for finely divided titanium dust, special engineering considerations shall be given to the design, installation, maintenance, and use of such systems.

5-3.7

Sludge from dust separators and vacuum-cleaning system precipitators shall be removed daily as a minimum. Covered, vented steel containers shall be used to transport collected sludge to a safe storage area or for disposal. Sludge shall be disposed of in accordance with federal, state, and local regulations.

5-4 Compressed Air Fittings.

To prevent potential explosions caused by inadvertently using high-pressure compressed air in place of low-pressure inert gas, fittings used on compressed air and inert gas line outlets shall not be interchangeable.

Chapter 6* Scrap Storage

6-1 Storage.

6-1.1

Open storage of sheet, plate, forgings, or massive pieces of scrap presents no fire risk and shall be permitted.

6-1.2

Open storage of sponge, chips, fines, and dust that are readily ignitable shall be isolated and segregated from other combustible materials and titanium scrap to prevent propagation of a fire.

Exception: Storage of materials in closed noncombustible containers shall not be subject to the requirements of 6-1.2.

Chapter 7* Titanium Powder Production and Use

7-1 Drying and Storage of Titanium Powder.

7-1.1

Wetted powder shall be dried at a temperature not exceeding 230°F (110°C).

7-1.2*

Drying rooms shall be of Type I construction, as defined by NFPA 220, *Standard on Types of Building Construction*. They shall be segregated as far as possible from other operations. Explosion venting for drying rooms shall be considered.

7-1.3

Titanium powder shall be stored in sealed containers in well-ventilated areas, and shall be kept free of combustibles. The containers shall be protected from damage.

7-2 Titanium Powder Handling.

7-2.1

Special care shall be taken to prevent spills or dispersions that produce dust clouds.

7-2.2

Special temperature controls shall be required on sintering furnaces that handle titanium parts that are fabricated from powder. Powder or dust shall not be permitted to accumulate in the furnace or near the heating elements. Furnaces shall be provided with inert atmospheres.

7-2.3*

To minimize the risk of fire or explosion hazards in the handling of dry titanium powders, the equipment and processes shall be designed by people knowledgeable in the hazards of titanium powders.

7-2.4 Electrical Installations.

All titanium powder production, drying, and packing areas shall be evaluated for fire and explosion hazards associated with the operation and shall be provided with approved electrical equipment for the hazardous location present, which shall be installed in accordance with the requirements of NFPA 70, *National Electrical Code*.

7-3 Personnel Safety Precautions.

Personnel handling dry titanium powder shall wear nonsparking shoes and noncombustible or flame-retardant clothing without pockets, cuffs, laps, or pleats in which powder can accumulate.

Chapter 8 Fire Prevention and Fire Protection

8-1 Fire Prevention.

The provisions of Chapter 8 shall apply to all titanium production process, handling, and storage operations.

8-1.1

Buildings shall comply with the applicable provisions of NFPA *101*, *Life Safety Code*.

8-1.2

Sponge discharged from dryers shall be collected in containers that have no larger than a 4000-lb (1814-kg) capacity. The collection area shall be well-ventilated and free from other combustible material.

8-1.3

Hot work permits shall be required in designated areas that contain exposed titanium fines, dust, or sponge where hot work is conducted. All hot work areas that require a permit shall be thoroughly cleaned of titanium fines, dust, or sponge before hot work is performed.

NOTE: For information on cutting and welding practices, see NFPA 51B, *Standard for Fire Prevention in Use of Cutting and Welding Processes*.

8-1.4*

All containers used to receive molten metal, molten magnesium, molten magnesium chloride, or liquid sodium shall be cleaned and dried thoroughly before using. All pieces of magnesium metal shall be clean and dry when charged to reactors.

8-1.5

Good housekeeping practices shall be maintained. Supplies shall be stored in an orderly manner with properly maintained aisles to permit regular inspection and segregation of incompatible materials. Supplies of materials in titanium processing areas shall be limited to amounts necessary for normal operation.

8-1.6

Ordinary combustible materials, such as paper, wood, cartons, and packing material, shall not be stored or permitted to accumulate in titanium processing areas unless necessary for the process, and then only in designated areas.

8-1.7

Regular, periodic cleaning of titanium dust and fines from buildings and machinery shall be carried out as frequently as conditions warrant. Dust and fines shall be removed to a safe storage or disposal area. Consideration shall be given to the potential ignition sources associated with the operation of equipment during the cleaning operation.

8-1.8

Regular inspections shall be conducted to detect the accumulation of excessive titanium dust, chips, or fines on any portions of buildings or machinery not regularly cleaned in daily operations. Records shall be kept of these inspections.

8-1.9

Combustible materials shall not be discarded in containers used for the collection of dust, swarf, or turnings.

8-1.10

Oil spills shall be cleaned up immediately.

8-1.11

Smoking shall be permitted only in designated areas. No smoking areas shall be posted with No Smoking signs.

8-1.12*

Boring, crushing, and drying equipment shall be properly electrically bonded and grounded to prevent accumulation of static electricity.

8-1.13

All electrical equipment and wiring in titanium production, processing, handling, and storage facilities shall comply with NFPA 70, *National Electrical Code*.

8-1.14

Nonsparking tools and utensils shall be used in handling titanium powder.

8-1.15*

All metal objects or equipment used in titanium operations shall be properly electrically bonded and grounded to prevent accumulations of static electricity.

8-1.16

Where titanium is collected or stored in containers, material-handling equipment with sufficient capability to remove any container from the immediate area in the case of an emergency shall be readily available.

8-1.17

Areas used for torch-cutting of massive pieces of scrap shall be kept free of combustible materials.

8-2* Fire Protection.

8-2.1*

Buildings or portions of buildings of noncombustible construction used principally for titanium storage or handling shall not be permitted to be equipped with automatic sprinkler protection.

Exception: Sprinkler systems installed in accordance with NFPA 13, Standard for the Installation of Sprinkler Systems, shall be permitted in areas where combustibles other than titanium create a more severe hazard than the titanium and where acceptable to an authority having jurisdiction who is knowledgeable of the hazards associated with titanium.

8-2.2

If required by the authority having jurisdiction, automatic sprinkler protection, installed in accordance with NFPA 13, *Standard for the Installation of Sprinkler Systems*, shall be provided for offices, repair shops, and warehouses not used for the storage of titanium sponge, fines, or chips.

8-2.3* Portable Fire Extinguishers.

8-2.3.1 Portable fire extinguishers shall be provided in accordance with NFPA 10, *Standard for Portable Fire Extinguishers*. Water-based or CO_2 extinguishers shall not be provided in areas containing titanium sponge, fines, or chips.

8-2.3.2 If portable extinguishers are to be used on metal fires, they shall be approved for use on Class D fires.

8-2.4*

Dry sodium chloride, or other dry chemicals or compounds suitable for extinguishment or containment of titanium fires, shall be permitted to be substituted for Class D fire extinguishers. These alternative agents shall be stored in a manner that ensures the agent's effectiveness.

Shovels or scoops shall be kept readily available adjacent to the containers. All extinguishing agent storage areas shall be clearly identified.

8-2.5

Titanium fines shall be segregated by storage in noncombustible drums or tote bins. Drums or tote bins of burning materials shall be moved away from processing equipment and out of buildings as rapidly as possible.

8-2.6*

When a fire occurs in processing equipment, material feed to the equipment shall be stopped. The equipment shall be kept in operation, unless continued operation will spread the fire.

Chapter 9 Referenced Publications

9-1

The following documents or portions thereof are referenced within this standard and shall be considered part of the requirements of this document. The edition indicated for each reference is the current edition as of the date of the NFPA issuance of this document.

9-1.1 NFPA Publications.

National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.

NFPA 10, *Standard for Portable Fire Extinguishers*, 1994 edition.

NFPA 13, *Standard for the Installation of Sprinkler Systems*, 1994 edition.

NFPA 30, *Flammable and Combustible Liquids Code*, 1993 edition.

NFPA 34, *Standard for Dipping and Coating Processes Using Flammable or Combustible Liquids*, 1995 edition.

NFPA 45, *Standard on Fire Protection for Laboratories Using Chemicals*, 1991 edition.

NFPA 70, *National Electrical Code*, 1996 edition.

NFPA 91, *Standard for Exhaust Systems for Air Conveying of Materials*, 1995 edition.

NFPA *101*, *Life Safety Code*, 1994 edition.

NFPA 220, *Standard on Types of Building Construction*, 1995 edition.

NFPA 480, *Standard for the Storage, Handling, and Processing of Magnesium Solids and Powders*, 1993 edition.

Appendix A Explanatory Material

This Appendix is not a part of the requirements of this NFPA document but is included for informational purposes only.

A-1-2

See Appendix B for supplementary information on titanium.

A-1-5 Approved.

The National Fire Protection Association does not approve, inspect, or certify any installations, procedures, equipment, or materials; nor does it approve or evaluate testing laboratories. In determining the acceptability of installations, procedures, equipment, or materials, the authority having jurisdiction may base acceptance on compliance with NFPA or other appropriate standards. In the absence of such standards, said authority may require evidence of proper installation, procedure, or use. The authority having jurisdiction may also refer to the listings or labeling practices of an organization concerned with product evaluations that is in a position to determine compliance with appropriate standards for the current production of listed items.

A-1-5 Authority Having Jurisdiction.

The phrase "authority having jurisdiction" is used in NFPA documents in a broad manner, since jurisdictions and approval agencies vary, as do their responsibilities. Where public safety is primary, the authority having jurisdiction may be a federal, state, local, or other regional department or individual such as a fire chief; fire marshal; chief of a fire prevention bureau, labor department, or health department; building official; electrical inspector; or others having statutory authority. For insurance purposes, an insurance inspection department, rating bureau, or other insurance company representative may be the authority having jurisdiction. In many circumstances, the property owner or his or her designated agent assumes the role of the authority having jurisdiction; at government installations, the commanding officer or departmental official may be the authority having jurisdiction.

A-1-5 Listed.

The means for identifying listed equipment may vary for each organization concerned with product evaluation, some of which do not recognize equipment as listed unless it is also labeled. The authority having jurisdiction should utilize the system employed by the listing organization to identify a listed product.

A-1-5 Titanium Chips.

Titanium chips vary in ease of ignition and rapidity of burning, depending on size and geometry. A light, fluffy chip ignites easily and burns vigorously while a heavy, compact chip ignites with difficulty and burns quite slowly.

A-1-5 Titanium Dust.

See NFPA 497B, *Recommended Practice for the Classification of Class II Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas*, or NFPA 497M, *Manual for Classification of Gases, Vapors, and Dusts for Electrical Equipment in Hazardous (Classified) Locations*, for information on explosibility parameters of combustible dusts.

A-1-5 Titanium Powder.

See NFPA 497B, *Recommended Practice for Classification of Class II Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas*, or NFPA 497M, *Manual for Classification of Gases, Vapors, and Dusts for Electrical Equipment in Hazardous (Classified) Locations*, for information on explosibility parameters of combustible dusts.

A-1-5 Titanium Sponge.

Titanium sponge can contain dust and fines that can become airborne when the material is handled. If present in sufficient quantity, the dust and fines can cause increased fire risk.

A-2-1.1

NFPA 68, *Guide for Venting of Deflagrations*, contains information on the subject of explosion venting.

A-2-1.3

Floors should be slightly crowned to prevent accumulation of water in the vicinity of reduction furnaces.

A-2-3.2

For information on guidelines for handling and storing chlorine, see *The Chlorine Manual* (*see C-1.2.4*).

A-2-3.3

Titanium tetrachloride in contact with moist air or water hydrolyzes to form hydrogen chloride gas and hydrochloric acid. Hydrogen chloride is toxic and highly irritating to the respiratory tract. If not immediately removed, titanium tetrachloride in contact with the eyes or skin will result in a double burn, one caused by the acid, the other caused by the heat of reaction. Any skin that is contacted by titanium tetrachloride should be wiped immediately and then flushed with a large amount of water. Eyes splashed with titanium tetrachloride also should be flushed with copious amounts of water.

A-2-4.4

A high-efficiency cyclone-type collector presents less hazard than a bag- or media-type collector and, except for extremely fine powders, usually operates with fairly high collection efficiency. Where cyclones are used, the exhaust fan discharges to atmosphere away from other operations. It should be recognized that there are some instances in which a centrifugal-type collector might be followed by a fabric or bag- or media-type collector or by a scrubber-type collector where particulate emissions are kept at a low level. The hazards of each collector should be recognized and protected against. In each instance, the fan is the last element downstream in the system. Because of the extreme hazard involved with a bag- or media-type collector, consideration should be given to a multiple-series cyclone with a liquid final stage.

Industry experience has clearly demonstrated that an eventual explosion can be expected where a bag- or media-type collector is used to collect titanium fines. Seldom, if ever, can the source of ignition be positively identified. In those unusual instances where it becomes necessary to collect very small fines for a specific commercial product, it is customary for the producer to employ a bag- or media-type collector. Since this presents a strong explosion potential, the bag- or media-type collector should be located a safe distance from buildings and personnel.

If a bag- or media-type collector is used, the shaking system or dust removal system can be such as to minimize sparking due to frictional contact or impact. Pneumatic or pulse-type shaking is more desirable because no mechanical moving parts are involved in the dusty atmosphere. If the bags are provided with grounding wires, they can be positively grounded through a low-resistance path to ground. Where bags are used, it is customary that the baghouse be protected by an alarm that indicates excessive pressure drop across the bags. An excess air temperature alarm is also frequently used. A bag- or media-type collector is customarily located at least 50 ft (15 m) from any other building or operation. It is not customary to permit personnel to be within 50 ft (15 m) of the collector during operation or when shaking bags. Explosion vents are usually built into the system, as described in NFPA 68, *Guide for Venting of Deflagrations*. Care is customarily exercised in locating the vents because of the possibility of blast damage to personnel or adjacent structures.

A-2-4.5

Information on spark-resistant fans and blowers can be found in AMCA Standards Handbook 99-0410-86, *Classification for Spark-Resistant Construction*, 1986.

A-2-5

Molten magnesium and molten magnesium chloride present an extremely dangerous fire and fume hazard, in addition to an explosion hazard, if in contact with water or residual moisture.

A-3

Unlike other metals, which can be melted, cast, or molded without unusual complications, titanium, because of its strong affinity for oxygen, hydrogen, and nitrogen and its tendency to become contaminated, is melted in special water or NaK-cooled copper crucibles under a vacuum or with an inert gas blanket of argon or helium. During the early years of the titanium industry, melting was done with a nonconsumable electrode, usually carbon.

The consumable electrode process using direct current electricity was developed to meet quality and process requirements. Nonconsumable copper electrode furnaces are now being used to process scrap.

During the 1950s, several titanium melting furnace explosions occurred when water inadvertently entered the melting crucibles during the melting operation. Three distinct types of explosions were evident: steam explosions produced by water contacting molten metal; chemical reaction between the molten metal and water; and explosion of free hydrogen generated by the chemical reaction. Also, if air entered the crucible at the same time, an air-hydrogen explosion would sometimes occur. All three types of explosions could occur in the same incident. The explosion hazard is present with any crucible that is water-cooled.

The use of liquid metal NaK (sodium-potassium alloy) as a crucible coolant has been developed for both laboratory and commercial installations. While the danger of furnace explosion due to leakage into the melt zone is reduced, the handling of NaK has its own inherent hazards. The reaction between NaK and water is violent.

A-3-1.4

The explosion that can occur due to the rapid phase transformation of water trapped below molten material takes place over a time span of approximately 10^{-5} to 10^{-4} seconds. This is faster than a condensed phase detonation. The required pressure-relief device would not be effective in safely relieving the rapid pressure build-up caused by the rapid phase transformation. It should be noted that the required pressure-relieving device is intended to safely relieve only much slower increases in pressure, such as might occur from small incursions of water onto the top of the molten metal.

A-3-2

The general process for shape-casting of titanium is the “skull-casting” process, where the material to be cast is melted as a consumable electrode in a tilting crucible. The power applied is normally somewhat higher than typical for ingot melting in order to develop a deep pool of molten metal. At the appropriate time in the melting cycle, the electrode is withdrawn and the casting poured. Vacuum or inert gas is provided to protect the metal from atmospheric contamination. The furnace crucible is made of copper and has water or NaK cooling. Due to the high power levels used, seams in the crucible should not be exposed to the electric arc or the molten metal.

A-3-2.1

Such ingots contain internal stresses that can cause them to shatter, even up to several days after being wetted.

A-3-2.5

Personnel entering furnace shells to conduct inspections or repair work should first make certain that any inert gas has been purged from the shell and that all pyrophoric residue has been removed. These residues might be combustible or pyrophoric and caution should be exercised.

A-4

Forging remains the most popular method of forming titanium because it is generally simpler and less costly than other forming processes. Gas or electric furnaces with accurate heat control are used to heat the metal into the proper forging range, which can vary from 1600°F to 2300°F (871°C to 1260°C). The rate of heat-up and final temperature must often be controlled precisely to achieve specific metallurgical and physical properties. Slabs, billets, and bar stock are produced by forging.

Large rounds of titanium are produced by lathe turning or by grinding forges. A considerable amount of titanium strip, coil, and duct, down to foil thickness, is produced from slabs on both continuous and hand mills. Wide sheets and plates of various thicknesses are produced on hand mills or plate-rolling mills. Temperature control during rolling is important. Shearing and straightening operations are necessary to trim sheets and plates to size, to straighten or flatten plates, or to straighten forged bar stock or extrusions. Titanium wire is produced from coils of rolled bar by drawing operations. Fastener stock is produced from coils of wire. Titanium tubing is produced by inert gas seam welding of rolled narrow strip. Heavy wall seamless tubing is produced by extrusion.

Special types of grinding operations are performed in mills. Swing grinders are used to spot grind ingots, slabs, billets, and bar stock. Centerless grinders are used to finish round bar and fastener stock. Strip in coil form is ground continuously and sheets are individually ground.

Cold saws and abrasive cut-off saws are used to cut billet and bar stock to length. Swarf, or finely divided metal particles, is produced by all sawing and grinding operations.

A-4-1.2

See NFPA 77, *Recommended Practice on Static Electricity*.

A-5-1

Improperly designed or dulled tools can produce high temperatures at the interface, causing ignition at the turnings, if an adequate coolant flow is not used.

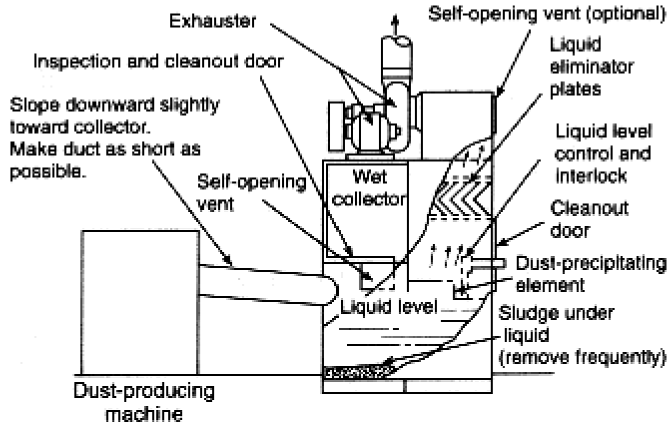


Figure A-5-3.1(a) Typical liquid precipitation separator for fixed dust-producing equipment.

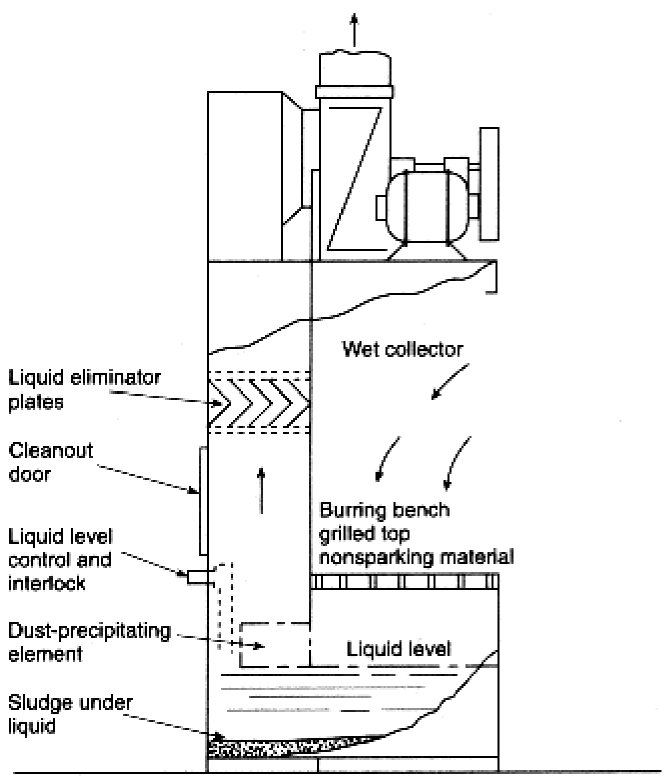


Figure A-5-3.1(b) Typical liquid precipitation separator for portable dust-producing equipment.

NOTE: These drawings are schematic and are intended only to indicate some of the features that are incorporated into the design of a separator. The volume of all dust-laden airspace is as small as possible.

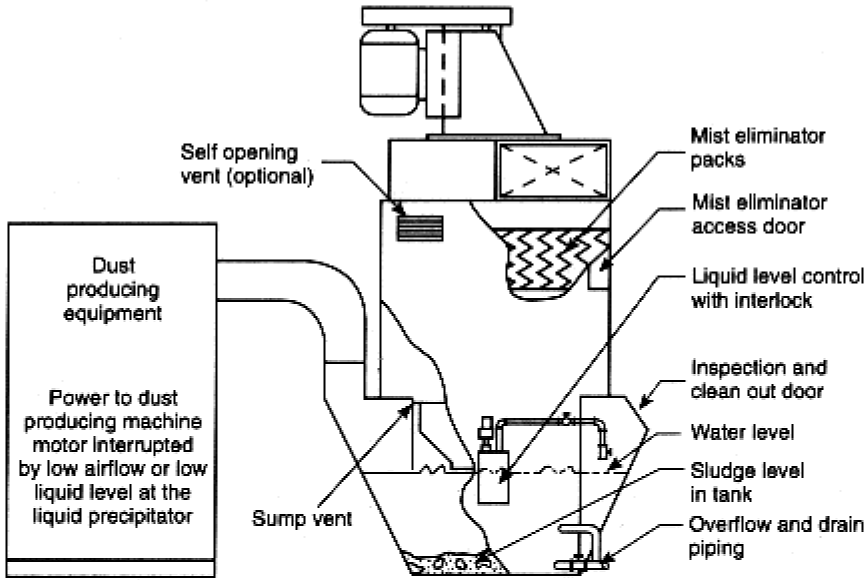


Figure A-5-3.1(c) Typical liquid precipitation separator for fixed dust-producing equipment.

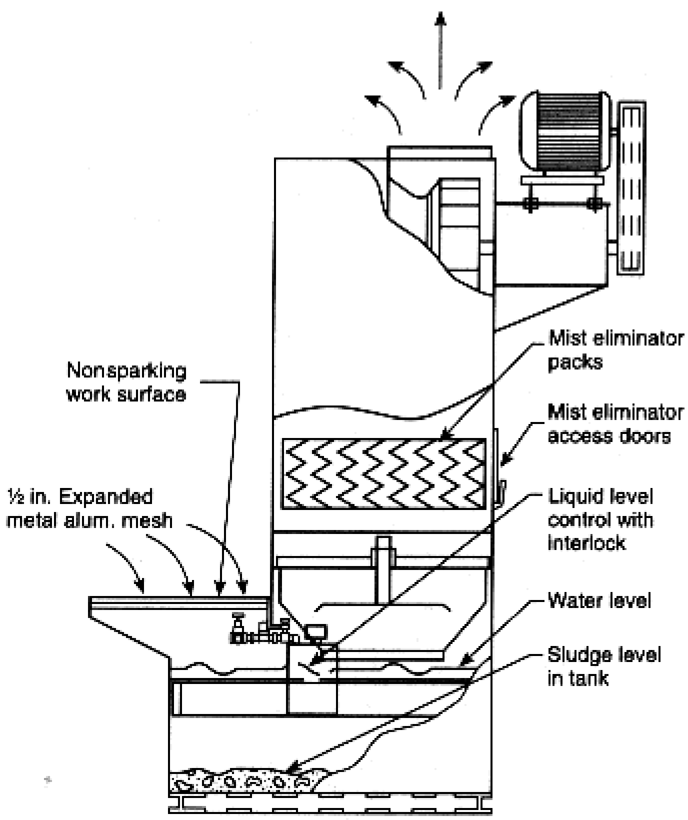


Figure A-5-3.1(d) Typical liquid precipitation separator for portable dust-producing equipment.

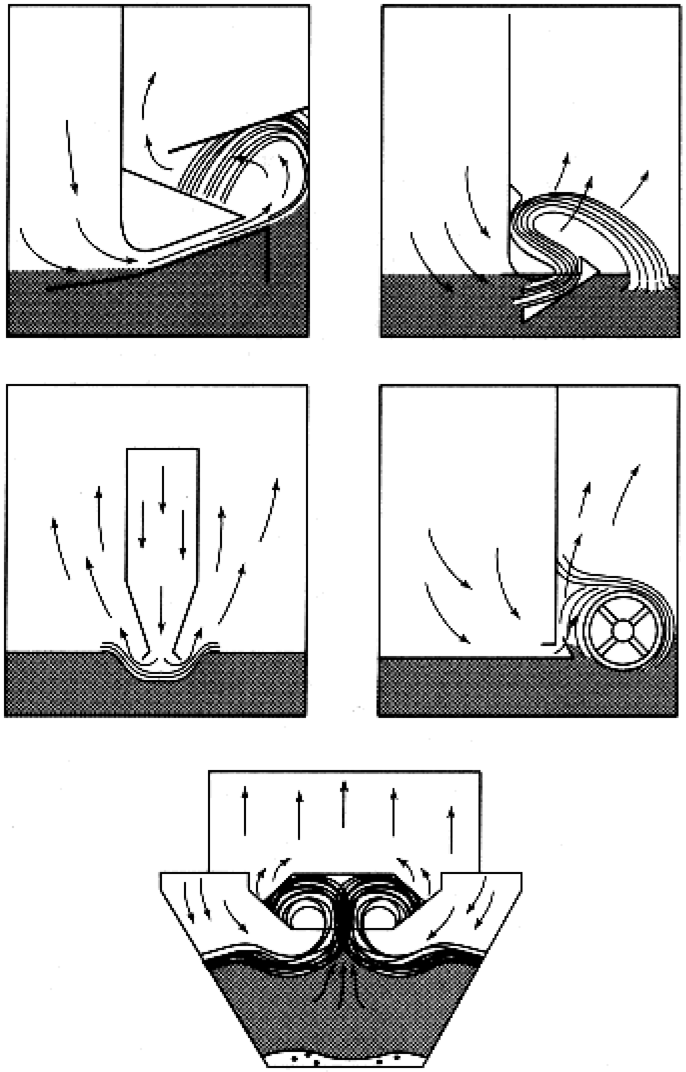


Figure A-5-3.1(e) Diagram of five methods of precipitating dust used in precipitators such as those shown in Figures A-5-3.1(a), (b), (c), and (d).

A-5-3.4

For example, iron oxide dusts are known to be incompatible with titanium due to the potential for an exothermic reaction. The dust-separating unit should be cleaned unless it has been determined that the materials exhibit no incompatibility.

A-6

Generation of titanium scrap from the sponge and melting processes through milling and fabrication is an inherent part of the titanium business. Scrap sponge, including some fines, is generated in the reduction, boring, crushing, leaching, and blending operations due to contamination and spills. Solid pieces of scrap titanium result in the melting process due to air or water contamination or due to malfunctions that cause interrupted melts.

During milling and fabrication, solid pieces of scrap result from forge, welding, and fabrication shops. Other scrap includes lathe turnings and clippings.

Before recycling, lathe turnings and clippings are usually crushed and degreased with a water-soluble detergent. Solid scrap is more difficult to handle. In one process, large pieces are torch-cut, then tumbled to remove slag, after which they are descaled in a basic chemical solution, washed in a sulfuric acid bath, and water-rinsed. Hydrogenation and crushing completes the preparation for recycling. Another method of handling fairly large chunks of titanium scrap is to weld them to the sides of consumable electrodes prior to melting.

A more recent development is the nonconsumable electrode furnace for melting scrap into ingot form. Equipped with a continuous feed through a vacuum interlock, these furnaces are capable of handling scrap pieces of baseball size.

A-7

Not all methods of producing metal powder are applicable to titanium. Reduction of titanium hydride and some forms of milling generally are used to produce the limited amounts of powder now required commercially. To reduce oxidation and possible ignition hazards, milling can be performed underwater or in an inert atmosphere of helium or argon. Some powders are given a very light copper coating during the manufacturing process.

Like many other metal powders, titanium is capable of forming explosive mixtures in air. The ignition temperatures of dust clouds, under laboratory test conditions, range from 330°C to 590°C (626°F to 1094°F). The minimum explosive concentration is 0.045 oz/ft^3 (0.045 kg/m^3). Maximum pressure produced in explosions in a closed bomb at a concentration of 0.5 oz/ft^3 (0.5 kg/m^3) ranged from 46 psi to 81 psi (317 kPa to 558 kPa). The average rate of pressure rise in these tests ranged from 250 psi/sec to 4300 psi/sec (1724 kPa/sec to 29 650 kPa/sec); the maximum rate of pressure rise ranged from 550 psi/sec to 10,000 psi/sec (3792 kPa/sec to over 68 950 kPa/sec). The minimum energy of electrical condenser discharge sparks required for ignition of a dust cloud was 10 millijoules; for a dust layer, the minimum value was 8 microjoules. Some samples of titanium powder were ignited by electric sparks in pure carbon dioxide, as well as in air. In some cases, titanium at elevated temperatures was found to react in nitrogen as well as in carbon dioxide. Titanium powder is considered a flammable solid. (See NFPA 491M, *Manual of Hazardous Chemical Reactions*.)

A-7-1.2

For information on designing explosion venting, see NFPA 68, *Guide for Venting of Deflagrations*.

A-7-2.3

The handling of dry titanium powder presents a fire and explosion hazard. The hazard increases as the size of the titanium particles decreases. The equipment and processes should be designed with consideration for the need to minimize the damage to property and risk to life resulting from fires and explosions involving titanium powders. Design considerations should include the use of deflagration venting, proper dust collection systems, inerting, or a combination of these methods. The inert gas used should be determined by test to be appropriate for the titanium powder being handled. Titanium powder can react exothermically in pure carbon dioxide atmospheres and in pure nitrogen atmospheres.

Tests have shown that the maximum oxygen concentrations allowed for different inert gases to prevent explosions are:

Carbon Dioxide	0 percent oxygen
Nitrogen	6 percent oxygen
Argon	4 percent oxygen
Helium	8 percent oxygen

This data was obtained from U.S. Bureau of Mines, Report of Investigations 3722, *Inflammability and Explosibility of Metal Powders*.

A-8-1.4

Molten magnesium and molten magnesium chloride present an extremely dangerous fire and fume hazard, in addition to an explosion hazard, if contacted with water or residual moisture.

A-8-1.12

See NFPA 77, *Recommended Practice on Static Electricity*.

A-8-1.15

See NFPA 77, *Recommended Practice on Static Electricity*.

A-8-2

The principal intent in fighting titanium fires is isolation and containment, rather than extinguishment. Water and other liquids have proven ineffective in extinguishing titanium sponge fires. Streams of water intensify the fire by feeding oxygen to it. There is also the possibility of causing a steam or hydrogen explosion, particularly if large amounts of sponge are involved. The great affinity of high-temperature titanium for oxygen will free a considerable amount of hydrogen, which can reach explosive concentrations in confined spaces. Entrapment of water under any burning or hot metal can result in a steam explosion.

A-8-2.1

Automatic sprinkler protection should not be recommended for blending and melting buildings.

A-8-2.3

Water-based extinguishers suitable for use on Class A fires should only be used on fires in ordinary combustibles. Extinguishers suitable for Class B fires are recommended for fires in oil, grease, and most flammable liquids. Extinguishers suitable for Class C fires should be used for fires in electrical equipment.

A-8-2.4

Experience has shown that dry sodium chloride is one of the most effective chemicals for containing fires involving titanium sponge or fines. Fire-fighting salts should be checked periodically to ensure that they have not become caked from moisture. Another effective chemical is a nonmetallic flux compound consisting of potassium chloride, magnesium chloride, and calcium fluoride. Commercial dry powder fire extinguishers or agents approved for use on combustible metals are also effective. Covering the fire completely reduces the accessible oxygen supply, thereby slowing the burning rate so that eventual extinguishment is reached.

A-8-2.6

Keeping the equipment in operation until all burning material is removed can reduce damage to the equipment. Small amounts of burning materials can be handled with a shovel to facilitate removal.

Appendix B Supplementary Information on Titanium

This Appendix is not a part of the requirements of this NFPA document but is included for informational purposes only.

B-1 Commercial Production.

Commercial production of titanium began in 1948 in a plant whose capacity was less than 20 tons (18,140 kg) per year. By 1951, the fulfillment of the needs of the military had brought about tremendous strides in the titanium industry. Large-scale commercial production had become a reality.

Titanium-bearing ores are plentiful and widely scattered throughout the world, including the United States, the principal ores being rutile and ilmenite. At present, rutile is the more desirable of the two for recovery of titanium. However, it is the ore in shortest supply, coming primarily from deposits in Australia, South Africa, and Sierra Leone.

It is generally recognized that, in time, the greatest tonnage of titanium might be processed from ilmenite ore. Ilmenite mines in the United States are located at Tahawas, NY; Highland, Starke, and Green Cove Springs, FL; and Manchester, NJ.

Titanium sponge is currently produced in the United States, Japan, England, and among countries in the former Soviet Union. Three basic processes have been developed for commercial refining of titanium from rutile ore. The most widely used processes employ magnesium or sodium to reduce titanium tetrachloride. An electrolytic process has been proven to be practical, and development of a commercial version is underway.

Titanium ingot is produced by arc-melting a consumable electrode of compacted sponge, or sponge and alloy, into a cooled copper mold under a low vacuum or an inert atmosphere.

B-2 Properties.

Titanium is a silver-gray light metal, about 60 percent heavier than aluminum, but only 56 percent as heavy as alloy steel. Its atomic weight is 47.90, specific gravity is 4.5, and melting point is 3140°F (1727°C). Titanium-based alloys are stronger than aluminum alloys and most alloy steels and have excellent ductility. They are superior to all the usual engineering metals and alloys in strength-weight ratio. Their fatigue resistance (ability to resist repeated flexures) is above that of heat-treated alloy steels and far greater than those of nonferrous metals. Titanium alloys are harder than aluminum and almost as hard as the high alloy steels. Surface hardness comparable to nitrided steel is obtainable.

Titanium is highly corrosion-resistant, being greatly superior to aluminum, considerably better than many specialty steels, and unique, compared to commonly available metals, in its immunity to saltwater and marine atmospheres. It is the only known structural metal that is highly resistant to simultaneous exposure to seawater and air. However, it is subject to stress corrosion cracking in methanol containing less than 0.8 percent water. Also, crevice corrosion can be expected in chlorine systems.

Titanium-based alloys can be subject to cracking during hot-forming operations if they are in contact with halide salts. Manufacturers' recommendations should be sought if applications are considered where high strength alloys are expected to come in contact with halide salts at temperatures above 500°F (260°C).

Impact resistance (capacity to withstand shock) of titanium is superior to that of aluminum; some titanium alloys approach heat-treated steel in impact resistance. Titanium alloys commonly lose strength above 1000°F (540°C) and can become embrittled after extended exposure to air at temperatures above 800°F (430°C).

Normal compositions of some widely used titanium alloys are:

Titanium 90 percent, Aluminum 6 percent, Vanadium 4 percent;

Titanium 92.5 percent, Aluminum 5 percent, Tin 2.5 percent;

Titanium 90 percent, Aluminum 8 percent, Molybdenum 1 percent, Vanadium 1 percent;

Titanium 86 percent, Aluminum 6 percent, Vanadium 6 percent, Tin 2 percent;

Titanium 92 percent, Manganese 8 percent.

Titanium presents some fire hazards during production of the raw sponge, melting of the sponge, casting, machining that produces fine turnings or chips, powder production and handling, and disposal of scrap containing chips or fines. However, because of its high temperature resistance properties in solid form, titanium sheet is extensively used for fire walls in jet aircraft and spacecraft.

In molten form, titanium either dissolves or is contaminated by every known refractory.

Slight contaminations apparently have little effect on the flammable characteristics of chips, turnings, or powder produced in machining operations, but might have an important bearing on ignition and explosion hazards associated with acid or salt baths.

Titanium combines readily with oxygen, nitrogen, and hydrogen at temperatures considerably below its melting point. Freshly exposed surfaces tend to form an adherent oxide coating quickly. This oxide coating is evidenced by discoloration that will dissolve as temperature increases. Excessive oxidation can cause embrittlement.

B-3 Tests for Titanium.

Two relatively simple methods are used to distinguish titanium from other metals.

(a) *Spark Test.* Distinctive sparks are thrown off when a piece of titanium is held against a grinding wheel. The white lines traced by the flying sparks end with a burst that produces several brilliant white rays or branches.

(b) *Glass Test.* The softer grades of titanium and titanium alloys are able to wet glass and can be identified by rubbing a moistened piece of the metal on a piece of glass. If the metal is relatively soft titanium, it will leave distinctive gray-white marks on the glass.

A portable metal spectroscope will better serve the purpose when attempting to identify titanium scrap by grade.

B-4 Applications.

While titanium has many uses, production is still largely consumed by commercial and military aircraft applications for use in jet engines, aircraft frames, and outer skin covering on subsonic and supersonic aircraft. Titanium is also being used in space vehicles and communications satellites. Other military uses include armor plate, electrical components, pontoons, cables, structural braces, fire walls, personnel helmets, and protective vests.

Titanium's virtually complete immunity to atmospheric and saltwater corrosion and to such agents as wet chlorine, nitric acid, and most oxidizing chemicals makes it attractive for chemical process applications such as heat exchangers, dryers, mixers, and other equipment.

Specially prepared, very finely divided titanium powders find limited application in powder metallurgy and other relatively small-scale uses.

B-5 Combustibility and Explosibility.

In tests conducted by the U.S. Bureau of Mines with titanium powders of less than 200 mesh, ignition of dust clouds in air was obtained at temperatures from 630°F to 1090°F (330°C to 590°C). Ignition of dust layers occurred at temperatures from 720°F to 950°F (380°C to 510°C). In some cases, dust clouds ignited at lower temperatures than static layers of the same dust. (See U.S. Bureau of Mines Report of Investigations 3722 and 4835, listed in Appendix C.) Titanium fines, nominally under 48 mesh, a by-product of sponge production and handling, and coarser particles, such as swarf from sawing and grinding operations, can be ignited by a spark.

Tests conducted by Underwriters Laboratories Inc. showed that dry ductile titanium in the form of thin chips and fine turnings could be ignited with a match. Normal size machine chips and turnings ignited and burned when heated in the flame of a Bunsen or blast burner. When ignited, titanium sponge or coarse turnings burn slowly with the release of a large quantity of heat, although a sponge fire can spread rather rapidly immediately after ignition.

Heavy castings or ingots of titanium can give some indication of burning when being cut with an oxyacetylene torch, but when enough surface is available to permit radiation cooling below the ignition temperature, burning ceases when the torch is removed.

Titanium can burn in atmospheres other than air. For example, one titanium powder sample, which ignited in air as a cloud at 900°F (480°C) and as a layer at 880°F (470°C), also ignited as a layer in pure carbon dioxide at 1260°F (680°C). At red heat, about 1300°F (704°C), titanium will decompose steam to free hydrogen and oxygen. Above 1470°F (801°C), titanium burns readily and vigorously in atmospheres of pure nitrogen.

Titanium will burn in the presence of dry chlorine or oxygen at room temperature. In oxygen, the combustion is not spontaneous and only occurs with oxygen concentration above 35 percent at pressures over 350 psig (2410 kPa gauge) when a fresh surface is created. The actual hazard in air is much less than that for aluminum.

B-6 Special Hazards.

In spite of titanium's superior resistance to corrosion, as discussed in Section B-2, titanium can react vigorously or even explosively with some hazardous materials. For example, extreme care should be taken when using titanium metal or powder in red fuming nitric acid. While no problems have been reported with normal nitric acid, explosions have occurred in laboratory tests involving titanium and red fuming nitric acid. These incidents have never been completely explained, although it is believed that the strength of the acid is a controlling factor and that some pyrophoric material is produced, which, when disturbed, releases enough heat to permit rapid oxidation of the metal. Potentially hazardous reactions between titanium and various chemicals are listed in NFPA 491M, *Manual of Hazardous Chemical Reactions*.

Low melting eutectics can form when titanium or its alloys are in contact with metals such as iron, nickel, or copper at high temperatures. Phase diagrams for titanium, such as those in the *ASM International Handbook*, Chapter on Metals Properties, should be consulted in such potential situations.

Titanium engages in thermite-type reactions with iron oxides.

Caution should be exercised in introducing titanium into process environments not previously investigated, since titanium can react and, in some cases, become pyrophoric.

B-7 Spontaneous Combustion.

Spontaneous ignition has occurred in fine, water-soluble, oil-coated titanium chips and swarf. Such fires, while probably due mostly to the presence of oil and certain contaminants, are very difficult to control and special precautions should be taken to have all fine scrap and oil-covered material removed from the plant and stored where any possible fire can be segregated and prevented from exposing other combustible material. Dry titanium fines collected in cyclones have, on occasion, ignited spontaneously when allowed to drop freely through the air. Also, sump fines will often ignite when they are dried.

During the early stages of the development of the titanium industry, thin titanium sheets were reported to have ignited spontaneously as they were removed from a sodium hydride descaling bath. However, the use of a potassium hydride solution in recent years has eliminated this problem.

Like any other metal in the high temperature molten state, titanium can cause a violently destructive explosion if water is present in any mold, pit, or depression into which the molten metal is poured or spilled. Under such circumstances, severe damage can be caused by steam pressure, an exothermic chemical reaction, or a low order hydrogen-air explosion.

In the 1950s, several violent explosions occurred in consumable electrode furnaces when water entered the furnace because of a crucible failure. The failures resulted from loss of cooling water flow and severe arc-through. A committee of industry representatives then prepared a set of general recommendations on design of melting furnaces to improve process safety. Their recommendations, given consideration in this standard, have been published by the Defense Metals Information Center of Battelle Memorial Institute. (*See Appendix C.*)

B-8 Process Description.

Current titanium production processes involve reduction of titanium tetrachloride to titanium metal. The titanium tetrachloride ($TiCl_4$) is made from rutile ore (approximately 95 percent titanium dioxide) by high temperature reaction with chlorine in the presence of a reducing agent, usually carbon. There are two basic commercially used processes for reduction of titanium: the Kroll-Bureau of Mines process, which uses magnesium as the reducing agent, and the sodium process, which uses liquid sodium as the reducing agent. Pilot plant work to develop a commercial electrolytic process is underway. The resulting product of all of the processes is referred to as titanium sponge.

In the Kroll-Bureau of Mines process, purified titanium tetrachloride is fed into a steel reaction chamber containing molten magnesium. The reduction takes place under an inert gas blanket of argon or helium and at temperatures between 1290°F (700°C) and 1650°F (900°C). The products of the reduction are magnesium chloride and titanium sponge, so called because of the spongy appearance of the titanium. The magnesium chloride is drawn off in the molten state for recycling or for reprocessing to magnesium and chlorine. After cooling, the sponge mass is bored from the reactor vessel and crushed in a "dry room." Any residual magnesium or magnesium chloride is removed by acid leaching or vacuum distilling. A modified version of the Kroll process involves vacuum distillation in the reaction vessel before removal of the sponge, thus eliminating the dry room. A detailed description of the Kroll process and equipment is contained in the Bureau of Mines' Report of Investigations No. 4879. Another description by Powell appears in American Institute of Chemical Engineers (AICHE) *Chemical Engineering Progress*, November, 1954. (*See Appendix C*.)

In the sodium reduction process, liquefied sodium is used as the reducing agent. In this process, the reaction vessel is heated to approximately 1830°F (1000°C) and no withdrawal of by-product during the reduction cycle is required. After completion of the reduction cycle, the reactor contains a solid mixture of titanium sponge and sodium chloride (called "spalt"). After the cooling cycle, this solid mixture is usually bored from the reaction vessel. A dry room is not required. The spalt is vacuum dried after removal from the reaction vessel. The sodium reduction process is described by Forbath in *Chemical Engineering*, March, 1958.

In the electrolytic process being developed, titanium tetrachloride is fed into a cell containing a molten salt bath (usually sodium chloride), where it is reduced to crystalline metal by fused salt electrolysis. The crystalline mass must be crushed, leached, and dried after removal from the cell. Although this process is commercially feasible, it has not yet been used significantly.

The titanium sponge fire risk is affected by the process used. The sodium reduction process and the electrolytic process produce a sponge that is less apt to be pyrophoric than magnesium-reduced sponge. The fines resulting from the crushing operation of these two processes, likewise, tend to be less pyrophoric.

Appendix C Referenced Publications

C-1

The following documents or portions thereof are referenced within this standard for informational purposes only and thus are not considered part of the requirements of this document. The edition indicated for each reference is the current edition as of the date of the NFPA issuance of this document.

C-1.1 NFPA Publications.

National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.

NFPA 51B, *Standard for Fire Prevention in Use of Cutting and Welding Processes*, 1994 edition.

NFPA 54, *National Fuel Gas Code*, 1992 edition.

NFPA 68, *Guide for Venting of Deflagrations*, 1994 edition.

NFPA 77, *Recommended Practice on Static Electricity*, 1993 edition.

NFPA 491M, *Manual of Hazardous Chemical Reactions*, 1991 edition.

NFPA 497B, *Recommended Practice for the Classification of Class II Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas*, 1991 edition.

NFPA 497M, *Manual for Classification of Gases, Vapors, and Dusts for Electrical Equipment in Hazardous (Classified) Locations*, 1991 edition.

C-1.2 Other Publications.

C-1.2.1 American Institute of Chemical Engineers Publication. American Institute of Chemical Engineers, 345 E. 47th St., New York, NY 10017.

Powell, R.L., *Chemical Engineering Progress*, November 1954, pp. 578-581.

C-1.2.2 AMCA Publication. Air Movement and Control Association, 30 W. University Drive, Arlington Heights, IL 60004-1893.

AMCA Standards Handbook 99-0410-86, *Classification for Spark-Resistant Construction*, 1986.

C-1.2.3 ASM International Publication. American Society of Metals, 9639 Kinsman, Materials Park, OH 44073-0002.

ASM International Handbook, Chapter on Metals Properties, 1980.

C-1.2.4 The Chlorine Institute Publication. The Chlorine Institute, Inc., 2001 L Street, NW, Washington, DC 20036.

The Chlorine Manual, 5th edition, 1986.

C-1.2.5 U.S. Bureau of Mines Publications. U.S. Bureau of Mines, Cochrans Mill Road, Pittsburgh, PA 15236-0070.

RI 3722, *Inflammability and Explosibility of Metal Powders*, I. Hartman, M.J. Nagy, and H.R. Brown, 1943.

RI 4835, *Explosive Characteristics of Titanium, Zirconium, Thorium, Uranium and their Hydrides*, 1951.

RI 4879, *Recent Practice at the Bureau of Mines*, Boulder City, NV, Plant, 1951.

C-1.2.6 Other Publications.

Forbath, T.P., "Sodium Reduction Route Yields Titanium," *Chemical Engineering*, McGraw Hill Publications Co., March 1958, pp. 124-127.

General Recommendations on Design Features for Titanium and Zirconium Production Melting Furnaces, Columbus, OH, Defense Metals Information Center, Battelle Memorial Institute.

Formal Interpretation

NFPA 481

Titanium

1995 Edition

Reference : Section 5-3
F.I. 87-1

Question: Is it the intent of the Committee that the requirements of Chapter 5, Machining & Fabrication; notably Section 5-3, Titanium Dust Collection; be applied to commercially pure titanium as well as the titanium alloys enumerated in Appendix B, Section B-2, Properties?

Answer: Yes.

Issue Edition: 1987
Reference: Section 5-6
Issue Date: July 17, 1991
Effective Date: August 6, 1991

NFPA 482

1996 Edition

Standard for the Production, Processing, Handling, and Storage of Zirconium

1996 Edition

This edition of NFPA 482, *Standard for the Production, Processing, Handling, and Storage of Zirconium*, was prepared by the Technical Committee on Combustible Metals and Metal Dusts and acted on by the National Fire Protection Association, Inc., at its Annual Meeting held May 20-23, 1996, in Boston, MA. It was issued by the Standards Council on July 18, 1996, with an effective date of August 9, 1996, and supersedes all previous editions.

This edition of NFPA 482 was approved as an American National Standard on July 26, 1996.

Origin and Development of NFPA 482

NFPA 482 was originally developed as a manual under the designation NFPA 482M, *Zirconium*. NFPA 482M was prepared by the Committee on Combustible Metals and officially adopted by the NFPA in 1959. It was amended in 1961, and the 1961 edition was reconfirmed in 1974.

In reviewing the 1974 edition, the Committee on Combustible Metals determined that NFPA 482M could be rewritten as a standard. Thus, where appropriate, all recommendations were expressed as requirements. Supplementary information was relocated to the appendices. The text was also rearranged to comply with the NFPA *Manual of Style*. This major rewrite resulted in the 1982 edition.

The 1987 edition was a reconfirmation of the 1982 edition.

For the 1996 edition, the committee has completely revised the standard to update the fire and dust explosion prevention measures and the requirements for safe handling of zirconium solids and powders. The committee revision has also incorporated editorial and style revisions to comply with the NFPA *Manual of Style* and to assist in making the document more usable and adoptable.

Technical Committee on
Combustible Metals and Metal Dusts

Robert W. Nelson, *Chair*
Industrial Risk Insurers, CT
Rep. Industrial Risk Insurers

Roy E. Adams, TIMET, NV
Rep. Titanium Development Assn.

Tom Christman, Martin Marietta Energy Systems, TN

R. Thomas Currin, Salisbury, NC

Ralph W. Hawk, Cyprus Foote Mineral Co., NC

Edward S. Krupinski, Marsh & McLennan, Inc., AZ

Kevin M. Laporte, Uni-Wash Inc., MI

Jeff D. Martin, Occupational Health Services, TN

John E. McConaghie, Reade Mfg. Co., Inc., NJ

Neil T. Morgan, Naval Undersea Warfare Engr Station, WA

Committee Scope: This Committee shall have primary responsibility for documents on safeguards against fire and explosion in the manufacturing, processing, handling, and storage of combustible metals, powders, and dusts.

NFPA 482
Standard for the
Production, Processing, Handling, and
Storage of Zirconium

1996 Edition

NOTICE: An asterisk (*) following the number or letter designating a paragraph indicates explanatory material on that paragraph in Appendix A.
Information on referenced publications can be found in Chapter 9 and Appendix C.

Chapter 1 General

1-1 Scope.

1-1.1*

This standard shall apply to the production, processing, handling, and storage of zirconium.

1-1.2

This standard also shall apply to finished parts and those materials, including scrap, that exhibit the burning characteristics of zirconium.

1-1.3

This standard shall not apply to the transportation of zirconium in any form on public highways and waterways, or by air or rail.

1-1.4

This standard shall not apply to those laboratories handling hazardous chemicals as defined in NFPA 45, *Standard on Fire Protection for Laboratories Using Chemicals*.

1-2* Purpose.

The purpose of this standard is to provide requirements addressing the fire and explosion hazards of zirconium and zirconium alloys in all forms and to outline requirements for fire prevention and protection.

1-3 Equivalency.

Nothing in this standard is intended to prevent the use of systems, methods, or devices that are equivalent or superior in quality, strength, fire resistance, effectiveness, durability, and safety to those prescribed by this standard, provided technical documentation is made available to the authority having jurisdiction that demonstrates equivalency and the system, method, or device is approved for the intended purpose.

1-4 Applicability.

The provisions of this document shall be considered necessary to provide a reasonable level of protection from loss of life and property from fire and explosion. They reflect situations and the state of the art prevalent at the time the standard was issued. Unless otherwise noted, it is not intended that the provisions of this document be applied to facilities, equipment, structures, or installations that existed or were approved for construction or installation prior to the effective date of the document, except in those cases where it is determined by the authority having jurisdiction that the existing situation involves a distinct hazard to life or adjacent property.

1-5 Definitions.

For the purpose of this standard, the following terms shall be defined as follows:

Approved.* Acceptable to the authority having jurisdiction.

Authority Having Jurisdiction.* The organization, office, or individual responsible for approving equipment, an installation, or a procedure.

Labeled. Equipment or materials to which has been attached a label, symbol, or other identifying mark of an organization that is acceptable to the authority having jurisdiction and concerned with product evaluation that maintains periodic inspection of production of labeled equipment or materials and by whose labeling the manufacturer indicates compliance with appropriate standards or performance in a specified manner.

Listed.* Equipment, materials, or services included in a list published by an organization acceptable to the authority having jurisdiction and concerned with evaluation of products or services that maintains periodic inspection of production of listed equipment or materials or periodic evaluation of services and whose listing states either that the equipment, material, or service meets identified standards or has been tested and found suitable for a specified purpose.

Media Collector. A bag house or a filter-type cartridge collector used for collecting dust.

Shall. Indicates a mandatory requirement.

Should. Indicates a recommendation or that which is advised but not required.

Zirconium. Pure metal or alloys having the generally recognized properties of zirconium metal, including the fire or explosion characteristics of zirconium in its various forms.

Zirconium Chips.* Particles produced from a cutting, machining, or grinding operation that are not oxidized and that are not diluted by noncombustible materials.

Zirconium Dust.* Any finely divided zirconium material 420 microns or smaller in diameter (material passing through a U.S. No. 40 standard sieve) that presents a fire or explosion hazard when dispersed and ignited in air.

Zirconium Fines. Zirconium particles that typically are 20 mesh and below that can be ignited in a static layer.

Zirconium Powder.* See Zirconium Dust and Zirconium Fines.

Zirconium Sponge.* Zirconium metal after it has been won from the ore but before it is melted.

Zirconium Swarf. Particles produced from a cutting, machining, or grinding operation that causes partial oxidation of the parent material or dilution by other inert materials.

Chapter 2 Sponge Production

2-1 Magnesium Operations.

All magnesium storage, handling, and processing operations in zirconium sponge production operations shall be in accordance with the requirements of NFPA 480, *Standard for the Storage, Handling, and Processing of Magnesium Solids and Powders*.

2-2 Plant Construction.

2-2.1*

Buildings housing reduction furnaces, boring and crushing facilities, and magnesium refining operations shall be constructed of noncombustible materials. Consideration shall be given to the provision of deflagration venting in accordance with current accepted practices.

2-2.2

Building exits shall comply with NFPA *101*®, *Life Safety Code*®.

2-2.3*

Floors in reduction, boring, and crushing facilities shall be made of noncombustible materials, such as concrete, brick, or steel plate.

2-2.4

Fittings used on compressed air and inert gas line outlets shall not be interchangeable to prevent potential explosions caused by inadvertently using compressed air in place of low pressure inert gas.

2-3 Processing Equipment.

2-3.1

Chlorinators and reduction vessels shall be designed and maintained to prevent water from entering the reaction chamber.

2-3.2

Furnaces shall be kept dry and free of iron scale and other foreign material.

2-3.3

Fuel supply lines to gas-fired furnaces or other gas-fired equipment shall be installed and maintained in accordance with NFPA 54, *National Fuel Gas Code*.

2-3.4*

Furnaces shall comply with NFPA 86C, *Standard for Industrial Furnaces Using a Special Processing Atmosphere*, and NFPA 86D, *Standard for Industrial Furnaces Using Vacuum as an Atmosphere*.

2-3.5

All electrically operated or controlled processing equipment shall be installed in accordance with NFPA 70, *National Electrical Code*®.

2-3.6

Back-up methods or systems shall be provided to allow for the safe and orderly shutdown of critical processes in the case of primary system failure.

2-4 Storage of Raw Materials.

2-4.1*

Chlorine shall be handled and stored in accordance with accepted industry practice.

2-4.2

Storage and handling of flammable and combustible liquids shall be in accordance with NFPA 30, *Flammable and Combustible Liquids Code*.

2-4.3*

Bulk containers of zirconium tetrachloride ($ZrCl_4$) and silicon tetrachloride ($SiCl_4$) shall be stored in a well-ventilated area located away from areas of acute hazard. Containers shall be identified plainly and tightly sealed until used.

2-5 Dust Collection.

2-5.1

Dust resulting from the crushing of zirconium sponge shall be managed safely to minimize the risk of fires and explosions.

2-5.2

Media collectors shall not be used for the collection of zirconium sponge fines.

2-5.3

Nonmedia based dry collectors shall be emptied before, or when, 80 percent of the storage capacity is attained. The maximum volume of zirconium fines collected before emptying shall not exceed 5 gal (19 L).

2-5.4*

Dust collectors for Kroll-distilled material shall be located outside buildings and shall be provided with deflagration vents.

2-5.5*

Fans that handle combustible dust and air mixtures shall be constructed of nonsparking materials and shall be constructed in accordance with NFPA 91, *Standard for Exhaust Systems for Air Conveying of Materials*.

2-6* Personnel Safety Precautions.

Personnel involved in reduction furnace tapping, removal of molten magnesium chloride, and magnesium refining and casting shall wear tight-fitting, above-the-ankle shoes, flame-retardant clothing, heat-resistant gloves, and face shields.

2-7 Sponge Storage.

2-7.1*

Dry zirconium sponge shall be stored in closed metal containers with a maximum capacity that is capable of being moved by available equipment. Wet zirconium sponge shall be stored in nonsealing, covered, metal containers with a maximum capacity that is capable of being moved by available equipment.

2-7.2

Zirconium storage areas shall be kept free of combustible materials, well-ventilated, equipped with the required fire protection equipment, and plainly marked with "no smoking" signs.

2-7.3

Where drums are used, storage shall be limited to one-drum tiers per pallet with a height of no more than four pallet loads. Stacked storage shall be arranged to ensure stability.

2-7.4

Aisles shall be provided for maneuverability of material-handling equipment, for accessibility, and to facilitate fire-fighting operations.

Chapter 3* Zirconium Melting

3-1 Explosion Prevention.

3-1.1

The water supply to crucibles shall be continuously monitored by a system that automatically interrupts power to the furnace upon a drop in water pressure or flow. In addition, an emergency source of cooling water shall be provided and shall be actuated automatically by flow interlock in the event of interruption of the primary cooling water.

3-1.2

Water-cooled furnaces shall have the crucible and its water jacket located in a protective noncombustible enclosure that provides a means of isolation to protect personnel and to minimize damage if an explosion occurs.

3-1.3*

The upper chamber of the furnace shall be provided with a pressure-relieving device to aid in safely relieving pressure if water enters the furnace. The release pressure of the pressure-relieving device shall be a maximum of 20 psig (138 kPa gauge).

3-1.4*

A clearance shall be maintained at all times between the electrode and the crucible wall to minimize arcing to the crucible wall.

3-1.5

The furnace shall be equipped with a device that continuously senses pressure within the furnace. The device shall automatically interrupt power to the melting heat source in the event of an unexpected sudden rise in pressure.

3-1.6

The furnace shall be equipped with the following:

(a) Water flow, temperature, and pressure sensors on all cooling systems;

(b) Arc voltage and melting power recorders;

(c) Electrode position indicators;

(d) Furnace pressure sensors and recorders; and

(e) Set point alarms on all systems to warn of abnormal conditions.

3-2* Casting.

3-2.1

The water supply to crucibles shall be monitored continuously by a system that automatically interrupts power to the melting heat source upon a drop in water pressure or flow. In addition, an emergency source of cooling water shall be provided and shall be actuated automatically by flow interlock in the event of interruption of the primary cooling water.

3-2.2

Molds for zirconium casting shall be made of material that is compatible with molten zirconium. Molds shall be dried thoroughly and stored carefully to prevent accumulation of moisture in the molds.

3-2.3

Since mold breaks are inevitable, the casting chamber shall be cooled or shall be large enough to serve as a heat sink, or both, in order to provide the protection necessary in the event of a spill.

3-2.4

Control consoles for water-cooled melting and casting operations shall be located remote from melting areas and outside of furnace enclosures.

3-2.5*

Residue from casting furnaces shall be placed in steel boxes and moved outside the building.

Chapter 4* Mill Operations

4-1 Fire Prevention.

4-1.1

Flammable or combustible liquids shall be handled in accordance with NFPA 30, *Flammable and Combustible Liquids Code*.

4-1.2*

All electrically-driven equipment used for sawing, cutting, or grinding operations shall be grounded in accordance with NFPA 70, *National Electrical Code*.

4-1.3

Zirconium chips shall be collected in covered metal containers and removed daily, as a minimum, to a safe storage or disposal area.

4-1.4

Forge presses, heavy grinders, and other milling equipment operated by hydraulic systems shall use a less hazardous hydraulic oil with a flash point greater than 200°F (93°C).

4-1.5

Nonflammable coolants shall be used for wet grinding, cutting, or sawing operations. The coolant shall be filtered on a continuous basis, and the collected solids shall not be permitted to accumulate in quantities greater than 5 gal (19 L) and shall be moved to a safe storage or disposal area.

4-1.6

Flammable or combustible liquid coatings applied to zirconium shall be used in accordance with the requirements of NFPA 34, *Standard for Dipping and Coating Processes Using Flammable or Combustible Liquids*.

4-1.7

Oily crushed lathe turnings, raw turnings, and chips shall be collected in covered metal containers and removed daily, as a minimum, to a safe storage or disposal area.

4-1.8

Furnaces or other heating equipment used for heating zirconium shall be free of iron scale or residue that could react exothermically with the metal being heated.

Chapter 5 Machining and Fabrication

5-1* Machining Operations.

5-1.1

Cutting tools shall be of proper design and shall be kept sharp for satisfactory work with zirconium.

5-1.2

Nonflammable coolants or lubricants shall be used to minimize heat generated by the cutting operation.

5-2 Welding.

5-2.1

All welding of zirconium shall be carried out under a helium or argon atmosphere, or under vacuum.

5-2.2*

Hot work such as electric arc or gas torch welding shall not be permitted in areas where zirconium powder or chips are produced, handled, packaged, or stored until all exposed chips or powder have been removed and exposed equipment has been cleaned thoroughly.

5-3 Zirconium Dust Collection.

5-3.1*

Zirconium dust shall be collected by means of hoods or enclosures at each dust-producing operation. The hoods or enclosures shall be connected to liquid precipitation separators, and the suction unit shall be installed so that the dust is converted to sludge without making contact, in the dry state, with any high-speed moving parts. [*See Figures A-5-3.1(a) through (e)*.]

5-3.2

Connecting ducts or suction tubes between points of collection and separators shall be completely bonded and grounded. Ducts and tubes shall be as short as practicable, with no unnecessary bends. Ducts shall be fabricated and installed in accordance with NFPA 91, *Standard for Exhaust Systems for Air Conveying of Materials*.

5-3.3

Zirconium dust-producing equipment shall be connected to dust-separating equipment. Multiple pieces of zirconium dust-producing equipment shall be permitted to be connected to a single zirconium dust-separating unit. An evaluation shall be made to determine if multiple pieces of dust-producing equipment can be safely served by a single dust-separating unit.

5-3.4*

If the zirconium dust-separating unit is to be used for other materials, it shall be thoroughly cleaned of all incompatible materials prior to and after its use.

5-3.5

The power supply to the dust-producing equipment shall be interlocked with the airflow from the exhaust blower and the liquid-level controller of the separator so that improper functioning of the dust collection system shuts down the equipment it serves. A time-delay switch or equivalent device shall be provided on the dust-producing equipment to prevent starting of its motor drive until the separator is in complete operation and several air changes have swept out any residual hydrogen.

5-3.6 Housekeeping (Dust).

5-3.6.1 Systematic cleaning of the entire building containing dust-producing equipment, including roof members, pipes, conduits, and other components, shall be conducted as conditions warrant. Cleaning methods shall be limited to those methods that minimize the probability of fire or explosion, as determined by a person knowledgeable in the properties of zirconium dust.

5-3.6.2 Due to the inherent hazards associated with the use of vacuum-cleaning systems for finely divided zirconium dust, special engineering considerations shall be given to the design, installation, maintenance, and use of such systems.

5-3.7*

Sludge from dust separators and vacuum-cleaning system precipitators shall be removed daily, as a minimum, and shall be kept thoroughly wet. Nonsealing, covered, metal containers shall be used to transport collected sludge to a safe storage area or for disposal. Sludge shall be disposed of in accordance with federal, state, and local regulations.

Chapter 6* Scrap Storage

6-1 Storage.

6-1.1

Open storage of sheet, plate, forgings, or massive pieces of scrap shall be permitted.

6-1.2

Storage of sponge, chips, fines, and dust that are readily ignitible shall be isolated and segregated from other combustible materials and zirconium scrap to prevent propagation of a fire.

Chapter 7* Zirconium Powder Production and Use

7-1 Drying and Storage of Zirconium Powder.

7-1.1*

Wetted powder shall be dried at a temperature not exceeding 230°F (110°C).

7-1.2*

Drying rooms shall be of Type I construction, as defined by NFPA 220, *Standard on Types of Building Construction*. They shall be segregated as far as practicable from other operations. Deflagration venting for drying rooms shall be considered.

7-1.3

Zirconium powder shall be stored in sealed containers in well-ventilated areas and shall be kept segregated from other combustibles. The containers shall be protected from damage.

7-2 Zirconium Powder Handling.

7-2.1

Special care shall be taken to prevent spills or dispersions that produce dust clouds.

7-2.2*

Sintering furnaces that handle zirconium parts that are fabricated from powder shall be installed and operated in accordance with NFPA 86C, *Standard for Industrial Furnaces Using a Special Processing Atmosphere*. Powder or dust shall not be permitted to accumulate in the furnace or near the heating elements. Furnaces shall be operated with inert atmospheres of helium or argon or under vacuum.

7-2.3

To minimize the risk of fire or explosion hazard in the handling of zirconium powders, the equipment and processes shall be designed by people knowledgeable in the hazards of zirconium powders.

7-2.4 Electrical Installations.

All zirconium powder production, drying, and packing areas shall be evaluated for fire and explosion hazards associated with the operation and shall be provided with approved electrical equipment suitable for the hazardous location. The electrical equipment shall be installed in accordance with the requirements of NFPA 70, *National Electrical Code*.

7-3 Personnel Safety Precautions.

Personnel handling zirconium powder shall wear nonsparking shoes and noncombustible or flame-retardant clothing that is designed to minimize the accumulation of zirconium powder.

7-4 Housekeeping Practices.

Good housekeeping practices shall be followed so that accumulations of powder are minimized. Special attention shall be paid to powder accumulations in crevices and joints between walls and floors.

Chapter 8 Fire Prevention and Fire Protection

8-1 Fire Prevention.

The provisions of Chapter 8 shall apply to all zirconium production processes, handling, and storage operations.

8-1.1

Buildings shall comply with the applicable provisions of NFPA *101*, *Life Safety Code*.

8-1.2

Sponge discharged from dryers shall be collected in containers with a maximum capacity of 4000 lb (1814 kg). The collection area shall be well-ventilated and free from other combustible materials.

8-1.3*

Hot work permits shall be required in designated areas that contain exposed zirconium chips, powder, or sponge. All hot work areas that require a permit shall be thoroughly cleaned of zirconium chips, powder, or sponge before hot work is performed.

8-1.4*

All containers used to receive molten metal, molten magnesium, molten magnesium chloride, or liquid sodium shall be cleaned and dried thoroughly before use. All pieces of magnesium metal shall be clean and dry where charged to reduction furnaces.

8-1.5

Good housekeeping practices shall be maintained. Supplies shall be stored in an orderly manner with properly maintained aisles to allow routine inspection and segregation of incompatible materials. Supplies of materials in zirconium processing areas shall be limited to those amounts necessary for normal operation.

8-1.6

Ordinary combustible materials, such as paper, wood, cartons, and packing material, shall not be stored or allowed to accumulate in zirconium processing areas.

Exception: This requirement shall not apply where ordinary combustible materials are necessary for the process and are stored in designated areas.

8-1.7*

Periodic cleaning of zirconium sponge, chips, or powder from buildings and machinery shall be carried out as frequently as conditions warrant. Sponge, chips, or powder shall be removed to a safe storage or disposal area.

8-1.8

Periodic inspections shall be conducted, as frequently as conditions warrant, to detect the accumulation of excessive zirconium sponge, chips, or powder on any portions of buildings or machinery not regularly cleaned during daily operations. Records of these inspections shall be kept.

8-1.9*

Ordinary combustible materials shall not be discarded in containers used for the collection of sponge, chips, or powder.

Exception: Floor sweepings from zirconium operations shall be permitted to contain small amounts of ordinary combustible materials.

8-1.10

Areas in which flammable and combustible liquids are used shall be in accordance with the requirements of NFPA 30, *Flammable and Combustible Liquids Code*.

8-1.11

Smoking shall not be permitted in areas where ignitible zirconium sponge, chips, or powder is present. Such areas shall be posted with "no smoking" signs.

Exception: Where smoking is prohibited throughout the entire plant, the use of signage shall be at the discretion of the facility management.

8-1.12

All electrical equipment and wiring in zirconium production, processing, handling, and storage facilities shall comply with NFPA 70, *National Electrical Code*.

8-1.13

Where using tools and utensils in areas handling zirconium powder, consideration shall be given to the risks associated with generating impact sparks and static electricity.

8-1.14*

Processing equipment used in zirconium operations shall be electrically bonded and grounded properly in order to prevent accumulations of static electricity.

8-1.15

Where zirconium is collected or stored in containers, material-handling equipment with sufficient capability to remove any container from the immediate area in the case of an emergency shall be readily available.

8-1.16

Areas used for torch-cutting of massive pieces of scrap shall be kept free of combustible materials.

8-2* General Fire Protection.

8-2.1

A fire protection plan shall be provided for all areas where zirconium is processed, handled, used, and stored.

8-2.2*

Buildings or portions of buildings of noncombustible construction principally used for zirconium storage or handling shall not be permitted to be equipped with automatic sprinkler protection.

Exception: Sprinkler systems installed in accordance with NFPA 13, Standard for the Installation of Sprinkler Systems, shall be permitted in areas where combustibles other than zirconium create a more severe hazard than the zirconium and where acceptable to an authority having jurisdiction who is knowledgeable of the hazards associated with zirconium.

8-2.3

If required by the authority having jurisdiction, automatic sprinkler protection, installed in accordance with NFPA 13, *Standard for the Installation of Sprinkler Systems*, shall be provided for offices, repair shops, and warehouses not used for the storage of zirconium sponge, powder, or chips.

8-2.4

As an alternative, a specially engineered fire protection system specifically designed to be compatible with the hazards present in the zirconium operation area shall be permitted to be installed in areas where combustible loading is essential to the process operation.

8-3 Extinguishing Agents and Application Techniques.

8-3.1

Only listed or approved Class D extinguishing agents or those tested and shown to be effective for extinguishing zirconium fires shall be permitted. A supply of extinguishing agent for manual application shall be kept within easy reach of personnel while they are working with zirconium. The quantity of extinguishing agents shall be sufficient to contain anticipated fires.

8-3.2

Agents intended for manual application shall be kept in identified containers. Container lids shall be secured in place to prevent agent contamination and to keep the agent free of moisture. Where large quantities of agent are expected to be needed, a clean, dry shovel shall be provided with the container. Where small amounts are needed, a hand scoop shall be provided with each container.

8-3.3

Portable or wheeled extinguishers approved for use on zirconium fires shall be permitted and shall be distributed in accordance with NFPA 10, *Standard for Portable Fire Extinguishers*.

8-3.4*

Portable fire extinguishers shall be provided in accordance with NFPA 10, *Standard for Portable Fire Extinguishers*. Water-based or CO_2 extinguishers shall not be provided in areas containing zirconium sponge, chips, or powder.

Exception: CO_2 extinguishers shall be permitted in areas containing zirconium for use on electrical fires. Such CO_2 extinguishers shall be clearly marked "not for use on zirconium fires."

8-3.5

The following agents shall not be used as extinguishing agents on a zirconium fire because of adverse reaction:

(a) Water;

(b) Gaseous-based foams;

(c) Halon; and

(d) Carbon dioxide.

8-3.6

An ABC dry chemical extinguisher and a B:C dry chemical extinguisher shall not be used as a zirconium fire extinguishing agent, but shall be permitted to be used on other classes of fires in the area where zirconium is present.

8-3.7*

Dry sodium chloride, or other dry chemicals or compounds suitable for extinguishment or containment of zirconium fires, shall be permitted to be substituted for Class D fire extinguishers. These alternative agents shall be stored in a manner that ensures the agent's effectiveness. Shovels or scoops shall be kept readily available adjacent to the containers. All extinguishing agent storage areas shall be clearly identified.

8-3.8

Zirconium fines shall be segregated by storage in noncombustible drums.

8-3.9*

Where a fire occurs in processing equipment, material feed to the equipment shall be stopped. When feed is stopped, the equipment shall be kept in operation.

Exception: Where continued operation of equipment would cause the spread of fire, it shall be stopped.

Chapter 9 Referenced Publications

9-1

The following documents or portions thereof are referenced within this standard and shall be considered part of the requirements of this document. The edition indicated for each reference is the current edition as of the date of the NFPA issuance of this document.

9-1.1 NFPA Publications.

National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.

NFPA 10, *Standard for Portable Fire Extinguishers*, 1994 edition.

NFPA 13, *Standard for the Installation of Sprinkler Systems*, 1996 edition.

NFPA 30, *Flammable and Combustible Liquids Code*, 1996 edition.

NFPA 34, *Standard for Dipping and Coating Processes Using Flammable or Combustible Liquids*, 1995 edition.

NFPA 45, *Standard on Fire Protection for Laboratories Using Chemicals*, 1996 edition.

NFPA 54, *National Fuel Gas Code*, 1996 edition.

NFPA 70, *National Electrical Code*, 1996 edition.

NFPA 86C, *Standard for Industrial Furnaces Using a Special Processing Atmosphere*, 1995 edition.

NFPA 86D, *Standard for Industrial Furnaces Using Vacuum as an Atmosphere*, 1995 edition.

NFPA 91, *Standard for Exhaust Systems for Air Conveying of Materials*, 1995 edition.

NFPA *101*, *Life Safety Code*, 1994 edition.

NFPA 220, *Standard on Types of Building Construction*, 1995 edition.

NFPA 480, *Standard for the Storage, Handling, and Processing of Magnesium Solids and Powders*, 1993 edition.

Appendix A Explanatory Material

This Appendix is not a part of the requirements of this NFPA document but is included for informational purposes only.

A-1-1.1 See Appendix B for supplementary information on zirconium.

A-1-2 See Appendix B for supplementary information on zirconium.

A-1-5 Approved. The National Fire Protection Association does not approve, inspect, or certify any installations, procedures, equipment, or materials; nor does it approve or evaluate testing laboratories. In determining the acceptability of installations, procedures, equipment, or materials, the authority having jurisdiction may base acceptance on compliance with NFPA or other appropriate standards. In the absence of such standards, said authority may require evidence of proper installation, procedure, or use. The authority having jurisdiction may also refer to the listings or labeling practices of an organization concerned with product evaluations that is in a position to determine compliance with appropriate standards for the current production of listed items.

A-1-5 Authority Having Jurisdiction. The phrase "authority having jurisdiction" is used in NFPA documents in a broad manner, since jurisdictions and approval agencies vary, as do their responsibilities. Where public safety is primary, the authority having jurisdiction may be a federal, state, local, or other regional department or individual such as a fire chief; fire marshal; chief of a fire prevention bureau, labor department, or health department; building official; electrical inspector; or others having statutory authority. For insurance purposes, an insurance inspection department, rating bureau, or other insurance company representative may be the authority having jurisdiction. In many circumstances, the property owner or his or her designated agent assumes the role of the authority having jurisdiction; at government installations, the commanding officer or departmental official may be the authority having jurisdiction.

A-1-5 Listed. The means for identifying listed equipment may vary for each organization concerned with product evaluation, some of which do not recognize equipment as listed unless it is also labeled. The authority having jurisdiction should utilize the system employed by the listing organization to identify a listed product.

A-1-5 Zirconium Chips. Zirconium chips vary in ease of ignition and rapidity of burning, depending on their size and geometry. A light, fluffy chip ignites easily and burns vigorously while a heavy, compact chip ignites with difficulty and burns quite slowly.

A-1-5 Zirconium Dust. See NFPA 497B, *Recommended Practice for the Classification of Class II Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas*, or NFPA 497M, *Manual for Classification of Gases, Vapors, and Dusts for Electrical Equipment in Hazardous (Classified) Locations*, for information on the explosibility parameters of combustible dusts.

A-1-5 Zirconium Powder. See NFPA 497B, *Recommended Practice for the Classification of Class II Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas*, or NFPA 497M, *Manual for Classification of Gases, Vapors, and Dusts for Electrical Equipment in Hazardous (Classified) Locations*, for information on the explosibility parameters of combustible dusts.

A-1-5 Zirconium Sponge. Zirconium sponge can contain dust and fines that can become airborne when the material is handled. If present in sufficient quantity, the dust and fines can cause increased fire risk.

A-2-2.1 NFPA 68, *Guide for Venting of Deflagrations*, contains information on the subject of deflagration venting.

A-2-2.3 Floors should be slightly crowned or drained to prevent the accumulation of water in the vicinity of reduction furnaces.

A-2-3.4 For additional information on ovens and furnaces, see NFPA 86, *Standard for Ovens and Furnaces*.

A-2-4.1 For information on guidelines for handling and storing chlorine, see *The Chlorine Manual*.

A-2-4.3 Zirconium tetrachloride in contact with moist air or water hydrolyzes to form hydrogen chloride gas and hydrochloric acid. Hydrogen chloride is toxic and highly irritating to the respiratory tract. If not immediately removed, zirconium tetrachloride in contact with the eyes or skin results in a double burn, one caused by the acid, the other caused by the heat of reaction. Any skin that comes in contact with zirconium tetrachloride should be wiped immediately and then flushed with a large amount of water. Eyes splashed with zirconium tetrachloride also should be flushed with copious amounts of water.

A-2-5.4 A high-efficiency cyclone-type collector presents less hazard than a bag-type or media-type collector and, except where collecting extremely fine powders, usually operates with fairly high collection efficiency. Where cyclones are used, the exhaust fan discharges to the atmosphere away from other operations. It should be recognized that there are some instances in which a centrifugal-type collector might be followed by a fabric or bag-type or media-type collector or by a scrubber-type collector where particulate emissions are kept at a low level. The hazards of each collector should be recognized and appropriate protection provided. In each instance, the fan is the last element downstream in the system. Because of the extreme hazard involved with a bag-type or media-type collector, consideration should be given to a multiple-series cyclone with a liquid final stage.

Industry experience has clearly demonstrated that an explosion ultimately can be expected where a bag-type or media-type collector is used to collect zirconium fines. Seldom, if ever, can the source of ignition be positively identified. In those unusual instances where it becomes necessary to collect very small fines for a specific commercial product, it is customary for the producer to employ a bag-type or media-type collector. Since this presents a strong explosion potential, the bag-type or media-type collector should be located a safe distance from buildings and personnel.

If a bag-type or media-type collector is used, the shaking system or dust removal system can be such that it minimizes sparking due to frictional contact or impact. Pneumatic or pulse-type shaking is recommended, because no mechanical moving parts are involved in the dusty atmosphere. If the bags are provided with grounding wires, they can be positively grounded through a low-resistance path-to-ground. Where bags are used, the baghouse should be protected by an alarm that indicates excessive pressure drop across the bags. An excess air temperature alarm also is frequently used. A bag-type or media-type collector should be located at least 50 ft (15 m) from any other building or operation. Personnel should not be permitted to be within 50 ft (15 m) of the collector during operation or when shaking bags. Deflagration vents usually are built into the system, in accordance with NFPA 68, *Guide for Venting of Deflagrations*. Care should be exercised in locating the vents because of the possibility of blast damage to personnel or adjacent structures.

A-2-5.5 Information on spark-resistant fans and blowers can be found in AMCA Standards Handbook 99-0410-86, *Classification for Spark-Resistant Construction*.

A-2-6 Molten magnesium and molten magnesium chloride present an extremely dangerous fire and fume hazard, in addition to an explosion hazard, where they come into contact with water or residual moisture.

A-2-7.1 Wet zirconium sponge has the potential to generate hydrogen gas. Sealed covers have the potential to confine hazardous accumulations of hydrogen within the container.

A-3 Unlike other metals, which can be melted, cast, or molded without unusual complications, zirconium, because of its strong affinity for oxygen, hydrogen, and nitrogen and its tendency to become contaminated, is melted in special water or NaK (sodium-potassium alloy)-cooled copper crucibles under a vacuum or with an inert gas blanket of argon or helium. During the early years of the zirconium industry, melting was done with a nonconsumable electrode, usually carbon.

The consumable electrode process using direct current electricity was developed to meet quality and process specifications.

During the 1950s, several zirconium melting furnace explosions occurred when water inadvertently entered the melting crucibles during the melting operation. Three distinct types of explosions were evident: steam explosions produced by water contacting molten metal; chemical reaction between the molten metal and water; and explosion of free hydrogen generated by the chemical reaction. Also, if air entered the crucible at the same time, an air-hydrogen explosion would sometimes occur. All three types of explosions could occur in a single incident. The explosion hazard is present with any crucible or electrode that is water-cooled.

The use of liquid metal NaK as a crucible coolant has been developed for both laboratory and commercial installations. While the danger of furnace explosion due to leakage into the melt zone is reduced, the handling of NaK has its own inherent hazards. The reaction between NaK and water is violent.

A-3-1.3 The explosion that can occur due to the rapid phase transformation and dissociation reaction of water in contact with molten material takes place over a time span of approximately 10^{-5} seconds to 10^{-4} seconds. This is faster than a condensed phase detonation. The required pressure-relieving device is not effective in safely relieving the rapid pressure build-up caused by the rapid phase transformation. It should be noted that the required pressure-relieving device is intended to relieve safely only much slower increases in pressure, such as might occur from small incursions of water onto the top of the molten metal. Following a breech in the vacuum system, air enters the furnace, which could create a secondary explosion due to the presence of hydrogen generated by the molten metal/water reaction.

A-3-1.4 The use of a magnetic field to deflect the electric arc away from the crucible wall should be considered.

A-3-2 The general process for shape casting of zirconium is the "skull-casting" process, where the material to be cast is melted as a consumable electrode in a tilting crucible. The power applied is normally somewhat higher than typical for ingot melting in order to develop a deep pool of molten metal. At the appropriate time in the melting cycle, the electrode is withdrawn and the casting is poured. A vacuum or inert gas is provided to protect the metal from atmospheric contamination. The furnace crucible is made of copper and uses water or NaK for cooling. Due to the high power levels used, seams in the crucible should not be exposed to the electric arc or the molten metal.

A-3-2.5 Personnel entering furnace shells to conduct inspections or repair work should first make certain that any inert gas has been purged from the shell (*see Title 29, Code of Federal Regulations, Part 1910.146*, *"Permit Required Confined Spaces*"). All combustible or pyrophoric residues should be removed or deactivated. Residues from casting furnaces are known to be combustible or pyrophoric and caution should be exercised.

A-4 Forging remains the most popular method of forming zirconium because it is generally simpler and less costly than other forming processes. Gas or electric furnaces with accurate heat control are used to heat the metal into the proper forging range, which can vary from 1600°F to 2300°F (871°C to 1260°C). The rate of heat-up and final temperature often should be controlled precisely to achieve specific metallurgical and physical properties. Slabs, billets, and bar stock are produced by forging.

Large rounds of zirconium are produced by lathe turning or by grinding forges. A considerable amount of zirconium strip, coil, and sheet in thicknesses as thin as those of foil is produced from slabs on both continuous mills and hand mills. Wide sheets and plates of various thicknesses are produced on hand mills or plate rolling mills. Temperature control during rolling is important. Shearing and straightening operations are necessary to trim sheets and plates to size, to straighten or flatten plates, or to straighten forged bar stock or extrusions. Zirconium wire is produced from coils of rolled bar by drawing operations. Fastener stock is produced from coils of wire. Zirconium tubing is produced by inert gas seam welding of rolled narrow strip. Heavy-wall seamless tubing is produced by extrusion.

Special types of grinding operations are performed in mills. Swing grinders are used to spot-grind ingots, slabs, billets, and bar stock. Centerless grinders are used to finish round bar and fastener stock. Strip in coil form is ground continuously and sheets are individually ground.

Cold saws and abrasive cut-off saws are used to cut billet and bar stock to length. Swarf, or finely divided metal particles, is produced by all sawing and grinding operations.

A-4-1.2 See NFPA 77, *Recommended Practice on Static Electricity,* in operations where static electricity presents a hazard.

A-5-1 If a sufficient coolant flow is not used, improperly designed or dull tools can produce high temperatures at the interface, causing ignition of the turnings.

A-5-2.2 Cleaning methodologies should consider the hazards of creating airborne dusts and the dangers associated with the use of vacuum cleaners.

A-5-3.1 See Figures A-5-3.1(a) through (e) for typical dust collector drawings.

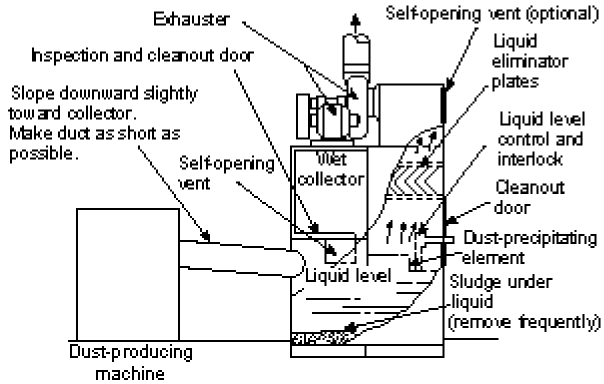


Figure A-5-3.1(a) Typical liquid precipitation separator for fixed dust-producing equipment.

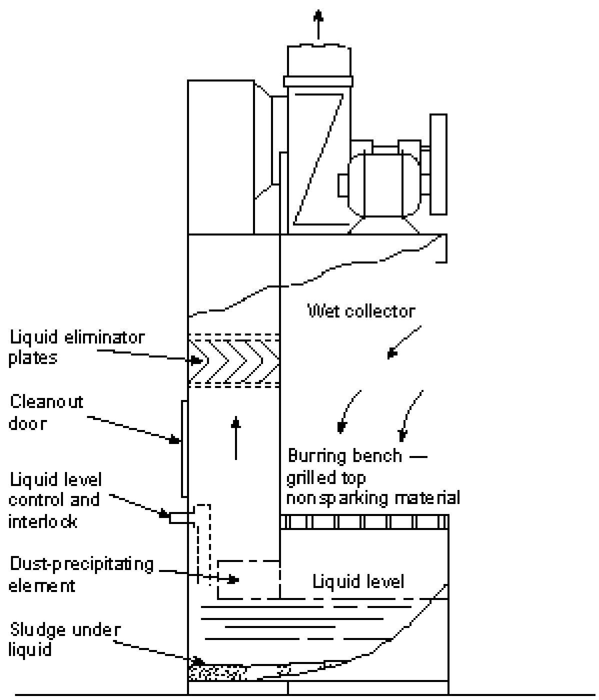


Figure A-5-3.1(b) Typical liquid precipitation separator for portable dust-producing equipment.

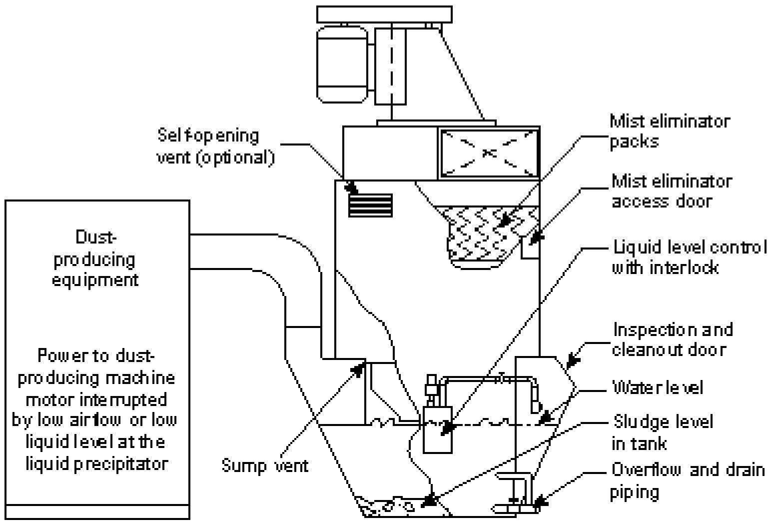


Figure A-5-3.1(c) Typical liquid precipitation separator for fixed dust-producing equipment.

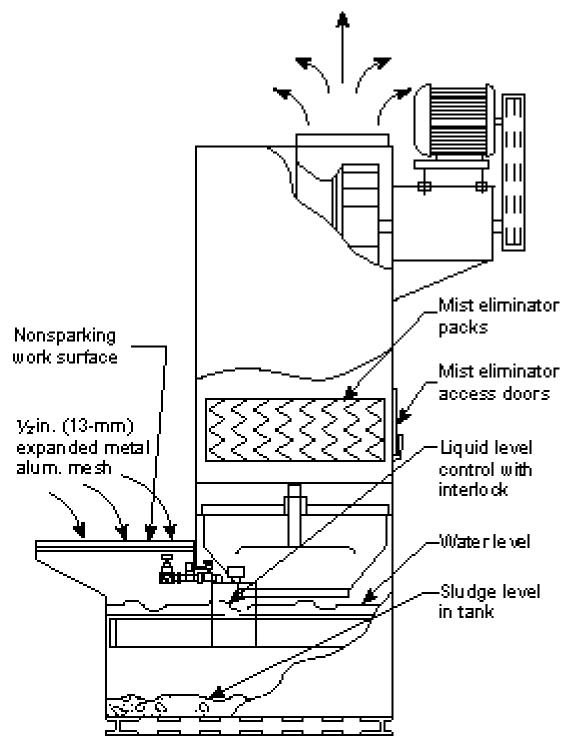


Figure A-5-3.1(d) Typical liquid precipitation separator for portable dust-producing equipment.

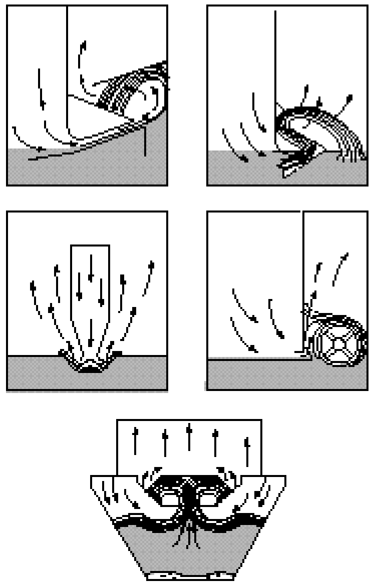


Figure A-5-3.1(e) Diagram of five methods of precipitating dust used in precipitators such as those shown in Figures A-5-3.1(a), (b), (c), and (d).

NOTE: These drawings are schematic and are intended only to illustrate some of the features that are incorporated into the design of a separator. The volume of all dust-laden air space is as small as possible.

A-5-3.4 For example, iron-oxide dusts are known to be incompatible with zirconium due to the potential for an exothermic reaction. The dust-separating unit should be cleaned, unless it has been determined that the materials exhibit no incompatibility.

A-5-3.7 Wet zirconium sludge has the potential to generate hydrogen gas. Sealed covers have the potential to confine hazardous accumulations of hydrogen within the container.

A-6 Generation of zirconium scrap from the sponge and melting processes through milling and fabrication is an inherent part of the zirconium business. Scrap sponge, including some fines, is generated in the reduction, boring, crushing, leaching, and blending operations due to contamination and spills. Solid pieces of scrap zirconium result in the melting process due to air or water contamination or due to malfunctions that cause interrupted melts.

During milling and fabrication, solid pieces of scrap result from forging, welding, and fabrication shops. Other scrap includes lathe turnings and clippings.

Before recycling, lathe turnings and chips are usually crushed, chopped, degreased, and compacted with a water-soluble detergent. Solid scrap is more difficult to handle. A method of handling fairly large chunks of zirconium scrap is to weld them to the sides of consumable electrodes prior to melting.

A more recent development is the nonconsumable electrode furnace for melting scrap into ingot form. Equipped with a continuous feed through a vacuum interlock, these furnaces are capable of handling scrap pieces of baseball size.

A-7 Not all methods of producing metal powder are applicable to zirconium. Reduction of zirconium hydride and some forms of milling are generally used to produce the limited amounts of powder now needed commercially. To reduce oxidation and possible ignition hazards, milling can be performed under water or in an inert atmosphere of helium or argon. Some powders are given a very light copper coating during the manufacturing process.

Like many other metal powders, zirconium is capable of forming explosive mixtures in air. The ignition temperatures of dust clouds, under laboratory test conditions, range from 626°F to 1094°F (330°C to 590°C). The minimum explosive concentration is 0.045 oz/ft^3 (45.1 g/m^3). The maximum pressure produced in explosions in a closed bomb at a concentration of 0.5 oz/ft^3 (500 g/m^3) ranged from 46 psi to 81 psi (317 kPa to 558 kPa). The average rate of pressure rise in these tests ranged from 250 psi/sec to 4300 psi/sec (1724 kPa/s to 29,670 kPa/s); the maximum rate of pressure rise ranged from 550 psi/sec to 10,000 psi/sec (3792 kPa/s to over 69,000 kPa/s). The minimum energy of electrical condenser discharge sparks necessary for ignition of a dust cloud was 10 millijoules; for a dust layer, the minimum value was 8 microjoules. Some samples of zirconium powder were ignited by electric sparks in pure carbon dioxide, as well as in air. In some cases, zirconium at elevated temperatures was found to react in nitrogen as well as in carbon dioxide. Zirconium powder is considered a flammable solid.

A-7-1.1 Experience has shown that the tendency for autoignition increases with decreasing particle size of the powder. In particular, in the range of 40 microns and below, the particles exhibit pyrophoric tendencies. This tendency is exacerbated in the presence of moisture.

A-7-1.2 For information on designing deflagration venting, see NFPA 68, *Guide for Venting of Deflagrations*.

A-7-2.2 The equipment and processes should be designed with consideration for the need to minimize the damage to property and risk to life resulting from fires and explosions involving zirconium powders. Design considerations should include the use of deflagration venting, proper dust collection systems, inerting, or a combination of these. The inert gas used should be determined by test to be appropriate for the zirconium powder being handled. Zirconium powder can react exothermically in pure carbon dioxide atmospheres and in pure nitrogen atmospheres.

Tests have shown that, to prevent explosions, the limiting oxygen concentrations for the inert gases argon and helium are 4.0 percent and 5.0 percent, respectively. (*See NFPA 69, Standard on Explosion Prevention Systems, for further information on limiting oxygen concentrations for safe handling of metal powders*.)

This data was obtained from U.S. Bureau of Mines, Report of Investigations 3722, *Inflammability and Explosibility of Metal Powders*, Report of Investigations 4835, *Explosive Characteristics of Titanium, Zirconium, Thorium, Uranium, and Their Hydrides*, and Report of Investigations 6516, *Explosibility of Metal Powders*.

A-8-1.3 For information on cutting and welding practices, see NFPA 51B, *Standard for Fire Prevention in Use of Cutting and Welding Processes*.

A-8-1.4 Molten magnesium and molten magnesium chloride present an extremely dangerous fire and fume hazard, in addition to an explosion hazard, where they come into contact with water or residual moisture.

A-8-1.7 Consideration should be given to the potential ignition sources associated with the operation of cleaning and processing equipment during the cleaning operation.

A-8-1.9 Special attention should be given to the segregation of ordinary trash and the routine collection of sponge, chips, and powder from floor sweepings as a function of housekeeping.

A-8-1.14 For information on static electricity, see NFPA 77, *Recommended Practice on Static Electricity.*

A-8-2 The objectives in fighting zirconium fires are isolation and containment, rather than extinguishment. Water and other liquids have proven ineffective in extinguishing zirconium fires. Streams of water intensify the fire by feeding it oxygen. There is also the possibility of causing a steam or hydrogen explosion, particularly if large amounts of zirconium are involved. The great affinity of high-temperature zirconium for oxygen frees a considerable amount of hydrogen, which can reach explosive concentrations in confined spaces. Entrapment of water under any burning or hot metal can result in a steam explosion.

Because of their unique nature, zirconium fires demand a comprehensive fire protection plan wherever zirconium is processed, handled, used, or stored. This plan should include specific actions in the event of a zirconium fire and should be coordinated with the local facility management, responding fire fighters, and medical personnel.

This plan should recognize the extreme hazards associated with zirconium-water reactions that might occur with sprinkler water. Specific attention should be given to an evacuation plan for personnel in the event of any release of water.

Properly trained personnel who work with zirconium know its hazards. Such personnel are best equipped to extinguish a zirconium fire in its incipient stage. Training should include sufficient information to determine if extinguishment can be accomplished safely and effectively.

A-8-2.2 Automatic sprinkler protection should not be used in buildings used for blending and melting.

A-8-3.4 Water-based extinguishers approved for use on Class A fires should be used only on fires involving ordinary combustibles. Extinguishers approved for Class B fires should be used for fires involving oil, grease, and most flammable liquids. Extinguishers approved for Class C fires should be used for fires involving electrical equipment.

A-8-3.7 Experience has shown that dry sodium chloride is one of the most effective chemicals for containing zirconium sponge or fines fires. Fire-fighting salts should be checked periodically to ensure that they have not become caked from moisture. Another effective chemical is a nonmetallic flux compound consisting of potassium chloride, magnesium chloride, and calcium fluoride. Commercial dry powder fire extinguishers or agents approved for use on combustible metals also are effective. Covering the fire completely reduces the accessible oxygen supply, thereby slowing the burning rate so that eventual extinguishment is achieved.

A-8-3.9 Keeping the equipment in operation until all burning material is removed can reduce damage to the equipment. Small amounts of burning materials can be handled with a shovel to facilitate removal.

Appendix B Supplementary Information on Zirconium

This Appendix is not a part of the requirements of this NFPA document but is included for informational purposes only.

B-1 History. Klaproth first reported the discovery of the element zirconium in 1789 during his analysis of the precious stone called jargon. Other chemists confirmed his discovery and, in 1797, Vauquelin reported on some of its properties and detailed its preparation. At that time, it was called zirconia. Berzelius first isolated the impure metal in 1824, but it was not until 1925 that the ductile metal was produced by van Arkel and deBoer, using their hot-wire reduction process.

A commercial-scale production process for making ductile zirconium was developed at the U.S. Bureau of Mines Laboratories where Dr. Wilhelm Kroll served as consultant and advisor for the process that bears his name.

B-2 Properties.

B-2.1 Zirconium is a silvery-gray metal having a close-packed hexagonal crystal structure at room temperature. At 1584°F (862°C), the crystal structure changes to a body-centered cubic structure. Both structures are very ductile, and the metal is easily machined, rolled, and extruded using conventional equipment and methods.

B-2.2 Some of the chemical and physical properties of zirconium are shown in Table B-2.2:

Table B-2.2 Physical Properties of Zirconium

Atomic number	40
Atomic weight	91.22
Atomic radius	1.60 angstrom units
Specific gravity	6.5
Melting point	3360°F (1850°C)
Boiling point	6475°F (3580°C)
Electronegativity	1.6
Valence	+4 (in most chemical reactions)

B-2.3 Zirconium has a very low capture cross section for thermal neutrons (0.18 barns). Its principal alloys have outstanding resistance to corrosion in water and steam at high temperatures. These properties make zirconium desirable as a cladding material for fuel elements in water-cooled nuclear power reactors. However, it becomes embrittled and loses strength on long-term exposure to air at temperatures above 1004°F (540°C).

B-3 Combustibility and Explosibility.

B-3.1 In laboratory tests, a dust cloud of fine particles of zirconium with an average particle diameter of 3.3 microns ignited spontaneously at 68°F (20°C). Powder having an average particle diameter of 17.9 microns would not ignite under similar circumstances until heated to 662°F (350°C). Similar clouds in carbon dioxide had to be heated to 1020°F (550°C) for ignition to occur. In atmospheres of air and helium, at least 5 percent oxygen had to be present to obtain spark ignition of zirconium dust clouds.

B-3.2 Layers of zirconium powder on hot surfaces ignited at 374°F (190°C) in air; at 1148°F (620°C) in carbon dioxide; and at 1454°F (790°C) in nitrogen.

B-3.3 The minimum explosive concentration for zirconium dust in air was found to be 0.04 oz/ft^3 (40.5 g/m^3). At concentrations of 1.0 oz/ft^3 (1000 g/m^3), the maximum explosion pressure was 76 psig to 78 psig (524 kPa gauge to 538 kPa gauge), and the maximum rate of pressure rise ranged from 9500 psi/sec to 10,000 psi/sec (65,500 kPa/s to 69,000 kPa/s). For further information, see U.S. Bureau of Mines Reports of Investigations 3722, *Inflammability and Explosibility of Metal Powders*, and Report of Investigations 4835, *Explosive Characteristics of Titanium, Zirconium, Thorium, Uranium, and Their Hydrides*.

B-4 Hazards.

B-4.1 Zirconium and its alloys do not present a serious risk where handled in most forms in which they are ultimately used (e.g., tubes, bars, and sheets). However, finely divided chips, turnings, or powder can be easily, sometimes spontaneously, ignited and can burn very rapidly. Although other potential hazards exist during melting, those that have resulted in the most serious and lethal accidents have been associated with the handling of zirconium powders, finely divided scrap, and so-called black reaction residues. For this reason, special precautions should be observed during handling or disposal of these materials.

Several companies have reported that fires have occurred while zirconium bars, plates, and other shapes were being chopped. A number of fires have occurred where hot or burning chips fell into accumulations of moist fines on or under lathes or milling machines. The most violent reactions have occurred where burning chips fell into drums or deep containers partially filled with moist turnings or scrap.

B-4.2 In the molten state, zirconium either dissolves or is contaminated by every known refractory. Slight contamination apparently has little effect on the flammable characteristics of chips, turnings, or powder produced in machining operations. However, such contamination should be avoided because of its effect during acid treatment, in salt baths, or during exposure in nuclear reactors.

B-4.3 At temperatures considerably below its melting point, zirconium or zirconium sponge readily combines with oxygen, nitrogen, carbon dioxide, hydrogen, and water vapor. Surface discoloration can indicate contamination. Contaminated sponge can present an increased combustion hazard.

B-5 Special Hazards.

B-5.1 A cloud of zirconium dust in air presents a serious flash fire hazard, as well as a potential explosion hazard. Accumulations of static dust on horizontal and vertical surfaces (e.g., beams, walls, ledges, ductwork) present the potential for a more serious dust explosion, since such static dust is likely to be thrown into suspension by the disturbance created by the ignition of a dust cloud in the same area. Therefore, the importance of preventing and controlling any dispersions of zirconium dust or powder warrants special emphasis. The provision of inert atmospheres in equipment and storage containers and the use of special cleaning equipment are two methods that aid in preventing explosions. Any dust deposits produced accidentally should be cleaned up promptly and the affected area washed down. All collected dust should be kept in small containers [1 gal (3.8 L) maximum] under water until disposal. Good housekeeping and prevention of ignition sources in areas where zirconium powder is handled are essential.

B-5.2 The burning rate of zirconium chips and turnings increases where water or water-soluble oils are present as a surface coating. The burning rate also increases with increasing pile depth, degree of confinement, and increasing void space in the pile. Chips and turnings less than 0.003 in. (0.08 mm) thick are particularly susceptible to rapid burning. Where all other factors are equal, partially wet material ignites more easily and burns more rapidly than dry material.

B-5.3 Small amounts of water tend to increase the risk of explosion. Additional heat is liberated on formation of the hydrated oxide, thereby increasing the chance of an explosion. Scrap that is fully immersed in water generally does not overheat because the water provides a substantial heat sink. However, with tight-packed, very finely divided zirconium, some risk might still be present.

B-5.4 Explosions can occur while immersing specimens of uranium alloys of 1 percent to 50 percent zirconium in nitric acid or while subsequently handling the clean, dry surface after nitric acid pickling. The formation of such explosive surface coatings can be mitigated by providing fluoride ions in the pickling bath. The fluoride should be in the form of 30 grams of ammonium fluoride per liter of 50 percent nitric acid/50 percent water solution.

B-5.5 There are incipient hazards associated with collected zirconium particulate where it is mixed with ordinary combustibles during cleanup or where it is mixed with laundry. Depending on the particular problems generated, management techniques should be developed to mitigate any hazards to the general public. Any and all zirconium wastes generated should be disposed of in accordance with all federal, state, and local regulations.

B-5.6 In the case of certain common metals, such as nickel and iron, zirconium can form eutectic mixtures that exhibit melting points much lower than the individual metals and can result in unexpected meltdown. The condition can be exacerbated by one or more of the materials being in a finely divided form.

B-6 Molten Metal and Water.

B-6.1 As with any other molten metal, a violently destructive explosion can occur if water is present in any mold, pit, or depression into which molten zirconium is poured or spilled. The damage might be the result of a steam explosion, an exothermic chemical reaction, a low-order hydrogen/air explosion, or a combination of these.

B-6.2 Several violent explosions have occurred in titanium melting furnaces using consumable electrodes. The explosions occurred when cooling water accidentally entered the furnace. These explosions are of interest to the zirconium production industry because of the chemical and physical similarities between titanium and zirconium and the fact that the same types of furnaces are used for both metals. These accidents resulted in the formation of a committee of industry representatives that prepared general guidelines for the design of titanium and zirconium melting furnaces. Their recommendations have been published by the Defense Metals Information Center of Battelle Memorial Institute and have been considered in the development of this standard.

B-7 Pickling of Zirconium. Several mineral acids are used in the production of zirconium sponge and mill shapes, including hydrochloric, nitric, sulfuric, and hydrofluoric acids. The acids are used to pickle the surfaces of zirconium ingots, to clean reaction vessels and copper crucibles, and to pickle and clean mill shapes of zirconium and its alloys. Care should be exercised to prevent overheating acid baths during pickling operations to prevent explosions. Acid supplies should be stored remote from production facilities.

B-8 Tests for Zirconium.

B-8.1 Several tests can be used in the identification of zirconium and its alloys. It is important that other metals are separated from zirconium alloys if the zirconium is to be recycled.

B-8.1.1 Spark Test. Titanium, zirconium, and hafnium produce a very brilliant spark when held against a grinding wheel. The white lines traced by the flying sparks end with bursts that produce several brilliant white rays or branches.

B-8.1.2 Glass Test. The softer grades of zirconium, titanium, and hafnium can be identified by rubbing a moistened piece of the metal on a piece of glass. The metal leaves distinctive gray-white marks on the glass.

B-8.1.3 Density Test. Titanium, zirconium, and hafnium can be separated by density measurement. Their densities are 4.54 g/cm^3, 6.50 g/cm^3, and 13.3 g/cm^3, respectively.

B-8.1.4 Spectroscope. The use of a portable metal spectroscope is best for identifying and separating zirconium alloys.

B-9 Zirconium Alloys.

B-9.1 The following nuclear grade zirconium alloys are available:

UNS R60001	99.5 percent Zr; 0.05 percent max. Fe and Cr; 0.005 percent max. H_2; 0.025 percent max. N_2; 0.05 percent max. C; 0.02 percent max. Hf.
UNS R60802	1.2 percent to 1.7 percent Sn; 0.07 percent to 0.2 percent Fe; 0.05 percent to 0.15 percent Cr; 0.03 to 0.08 percent Ni; balance percent Zr.
UNS R60804	1.2 percent to 1.7 percent Sn; 0.18 percent to 0.24 percent Fe; 0.07 percent to 0.13 percent Cr; balance, Zr.
UNS R60901	96 percent Zr; 3 percent Nb; 1 percent Sn.

B-9.2 Non-nuclear grades of the alloys specified in B-9.1 are available and contain up to 4.5

percent hafnium. (*See Table B-9.2.*)

Table B-9.2 Nuclear and Non-nuclear Zirconium Alloy Grades

Nuclear Grade	Non-nuclear Grade
R60001	701
R60802	702
R60804	704
R60901	705 (tentative)

B-10 Applications.

B-10.1 One of the major uses of zirconium alloys is in the nuclear field where it is used for the cladding of fuel elements of water-cooled power reactors.

B-10.2 Zirconium alloys are used for chemical process equipment and chemistry laboratory equipment. They also are used as filament material for photo flashbulbs.

B-10.3 In zirconium processing and production plants, zirconium is used for critical parts where corrosion resistance and minimal contamination are of extreme importance. Some typical applications include raffinate storage vessels, venturi scrubbers, pollution control piping and ducts, fan housings and blades, heat exchanger shells and tubes, and other equipment exposed to chloride attack.

B-10.4 Zirconium is an efficient gettering agent for removing hydrogen, oxygen, nitrogen, and carbon dioxide from vacuum tubes. Where alloyed with titanium at a ratio of 66 percent Zr to 34 percent Ti, zirconium gettering efficiency is increased.

B-10.5 In powder form, zirconium is used as an ingredient in lighter flints and in the pyrotechnic component of safety flares.

B-10.6 Zirconium sheet is formed into special crucibles used for sodium peroxide fusions conducted in analytical chemistry laboratories.

B-11 Production.

B-11.1 Zircon-bearing sand is found throughout the world, including the United States. The most abundant mineral containing zirconium is zircon; the second is baddeleyite (ZrO_2). Only zircon is used currently for the production of zirconium.

B-11.2 The element hafnium is associated with zirconium in each of the two ores. In zircon, it is present in the ratio of one part hafnium to 49 parts zirconium. Most of this hafnium is removed by liquid-liquid extraction in glass columns before the zirconium can be used for nuclear grade alloys.

B-11.3 The production of zirconium begins with the manufacture of zirconium tetrachloride ($ZrCl_4$) by high-temperature reaction with chlorine (Cl_2) in the presence of a reducing agent, usually carbon. The zirconium tetrachloride is made into zirconium sponge by means of the Kroll process.

B-11.4 In the Kroll process, zirconium tetrachloride vapor is fed to a steel reaction chamber containing molten magnesium. The reduction is carried out under an inert atmosphere of dry argon or helium at 1292°F to 1652°F (700°C to 900°C), with magnesium chloride formed as a by-product. Any residual magnesium chloride or magnesium is vacuum-distilled from the reaction chamber, leaving behind a porous form of zirconium called "sponge."

The reactor is cooled to 122°F (50°C) and the sponge treated with air for a short period to reduce the possibility of igniting the sponge. The reactor then is evacuated, backfilled with inert gas, and cooled to 68°F (20°C). The sponge then is removed, crushed, and sized.

B-11.5 An electrolytic process for producing zirconium is currently under development. In this process, zirconium tetrachloride is fed to a fused salt bath containing sodium chloride and other materials. The zirconium produced is a crystalline form of the metal that then is crushed and leached.

B-11.6 Zirconium ingot is produced by arc-melting a consumable electrode of compacted sponge (or sponge and alloy) in a cooled copper crucible. The molten metal is protected by a vacuum or an inert atmosphere.

Appendix C Referenced Publications

C-1 The following documents or portions thereof are referenced within this standard for informational purposes only and thus are not considered part of the requirements of this document. The edition indicated for each reference is the current edition as of the date of the NFPA issuance of this document.

C-1.1 NFPA Publications. National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.

NFPA 51B, *Standard for Fire Prevention in Use of Cutting and Welding Processes*, 1994 edition.

NFPA 68, *Guide for Venting of Deflagrations*, 1994 edition.

NFPA 69, *Standard on Explosion Prevention Systems*, 1992 edition.

NFPA 77, *Recommended Practice on Static Electricity*, 1993 edition.

NFPA 86, *Standard for Ovens and Furnaces*, 1995 edition.

NFPA 497B, *Recommended Practice for the Classification of Class II Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas*, 1991 edition.

NFPA 497M, *Manual for Classification of Gases, Vapors, and Dusts for Electrical Equipment in Hazardous (Classified) Locations*, 1991 edition.

C-1.2 Other Publications.

C-1.2.1 AMCA Publication. Air Movement and Control Association, 30 West University Drive, Arlington Heights, IL 60004.

AMCA Standards Handbook 99-0410, *Classification for Spark-Resistant Construction*, 1986.

C-1.2.2 Battelle Memorial Institute Publications. Battelle Memorial Institute, Defense Metals Information Center, Columbus, OH.

General Recommendations of Design Features for Titanium and Zirconium Production-Melting Furnaces, 1961.

C-1.2.3 Chlorine Institute Publication. The Chlorine Institute, Inc., 2001 L Street NW, No. 506, Washington, DC 20036.

The Chlorine Manual, 5th edition, 1986.

C-1.2.4 U.S. Bureau of Mines Publications. U.S. Bureau of Mines, Cochrans Mill Road, Pittsburgh, PA 15236-0070.

RI 3722, *Inflammability and Explosibility of Metal Powders*, I. Hartman, J. Nogy, and H. R. Brown, 1943.

RI 4835, *Explosive Characteristics of Titanium, Zirconium, Thorium, Uranium, and Their Hydrides*, 1951.

RI 6516, *Explosibility of Metal Powders*, M. Jacobsen, A. R. Cooper, and J. Nagy, 1964.

C-1.2.5 U.S. Government Publication. U.S. Government Printing Office, Superintendent of Documents, Washington, DC 20402.

Title 29, *Code of Federal Regulations*, Part 1910.146.

NFPA 485

1994 Edition

Standard for the Storage, Handling, Processing, and Use of Lithium Metal

1994 Edition

This edition of NFPA 485, *Standard for the Storage, Handling, Processing, and Use of Lithium Metal*, was prepared by the Technical Committee on Combustible Metals and Metal Dusts and acted on by the National Fire Protection Association, Inc., at its Annual Meeting held May 16-18, 1994, in San Francisco, CA. It was issued by the Standards Council on July 14, 1994, with an effective date of August 5, 1994.

The 1994 edition of this document has been approved by the American National Standards Institute.

Origin and Development of NFPA 485

The Committee on Combustible Metals and Metal Dusts began its work on developing a proposed standard on lithium at a Committee meeting in December 1990. The Committee reviewed drafts of the proposed standard and continued to revise the draft standard at Committee meetings held in June 1991, October 1991, March 1992, November 1992, March 1993, and November 1993.

The standard was submitted and adopted at the 1994 Annual Meeting in San Francisco, CA, May 16-18, 1994. The 1994 edition is the first edition of this standard.

Technical Committee on Combustible Metals and Metal Dusts

Robert W. Nelson, *Chair*
Industrial Risk Insurers, CT

Richard J. Biehl, Ansul Fire Protection, WI
Rep. Fire Equipment Mfrs. Assn. Inc.

Ralph W. Hawk, Cyprus Foote Mineral Co., NC

Ron A. Kirsch, Occupational Health Services Inc., TN

Edward S. Krupinski, M & M Protection Consultants, AZ

Kevin M. Laporte, Uni-Wash Inc., MI

John E. McConaghie, Reade Mfg. Co., NJ

Neil T. Morgan, Naval Undersea Warfare Engineering Station, WA

David L. Oberholtzer, Valimet, Inc., CA
Rep. The Aluminum Assn.

Eldon R. Poulsen, TiMET/TDA, NV

James A. Robertson, Dow Chemical Co. U.S.A., TX

Peter E. Rogers, Wolcott, VT

Waldemar Seton, SJO Consulting Engineers, OR

John Valiulis, Factory Mutual Research Corp., MA

Alternates

Edward D. Leedy, Industrial Risk Insurers, IL

(Alt. to R. W. Nelson)

Larry J. Moore, Factory Mutual Research, MA
(Alt. to J. Valiulis)

Nonvoting

Albert Muller, Lebanon, NJ
(Member Emeritus)

Martha H. Curtis, NFPA Staff Liaison

This list represents the membership at the time the Committee was balloted on the text of this edition. Since that time, changes in the membership may have occurred.

NOTE: Membership on a Committee shall not in and of itself constitute an endorsement of the Association or any document developed by the Committee on which the member serves.

Committee Scope: This Committee shall have primary responsibility for documents on safeguards against fire and explosion in the manufacturing, processing, handling, and storage of combustible metals, powders, and dusts.

NFPA 485

Standard for the

Storage, Handling, Processing,

and Use of Lithium Metal

1994 Edition

NOTICE: An asterisk (*) following the number or letter designating a paragraph indicates explanatory material on that paragraph in Appendix A.
Information on referenced publications can be found in Chapter 8 and Appendix B.

Chapter 1 General

1-1 Scope.

1-1.1

This standard shall apply to the storage, handling, processing, and use of solid or molten lithium.

1-1.2*

This standard shall also apply to finished parts and those materials, including scrap, that exhibit the burning characteristics of lithium as specified by the manufacturer.

1-1.3

This standard shall not apply to the primary production of lithium solid.

1-1.4

This standard shall not apply to the transportation of lithium.

1-1.5

This standard shall not apply to those laboratories handling hazardous chemicals as defined in NFPA 45, *Standard on Fire Protection for Laboratories Using Chemicals*.

1-1.6*

This standard shall not apply to finely divided solid forms of dry lithium or finely divided lithium dispersed in a flammable liquid.

1-2 Applicability.

Unless otherwise noted, it is not intended that the provisions of this document be applied to facilities, equipment, structures, or installations that were existing or approved for construction or installation prior to the effective date of the document, except in those cases where it is determined by the authority having jurisdiction that the existing situation involves a distinct hazard to life or adjacent property.

1-3 Purpose.

The purpose of this standard shall be to call attention to the fire and explosion hazard in the storage, handling, processing, and use of lithium; to emphasize the measures to be taken to reduce such hazards; and to minimize the frequency and severity of lithium-related fire and explosion incidents. The requirements of this standard are based on conclusions drawn from available reports and data on lithium fire tests and actual fire experience.

1-4 Equivalency.

Nothing in this standard is intended to prevent the use of systems, methods, or devices of equivalent or superior quality, strength, fire resistance, effectiveness, durability, and safety over those prescribed by this standard, provided technical documentation is made available to the authority having jurisdiction to demonstrate equivalency and the system, method, or device is approved for the intended purpose.

1-5 Definitions.

For the purpose of this standard, the following terms shall have the meanings given below.

Approved.* Acceptable to the authority having jurisdiction.

Authority Having Jurisdiction.* The organization, office, or individual responsible for approving equipment, an installation, or a procedure.

Handling. Any activity, including processing, that can expose the metal's surface to air or any other substance capable of reacting with the metal under the conditions of the exposure.

Labeled. Equipment or materials to which has been attached a label, symbol, or other identifying mark of an organization that is acceptable to the authority having jurisdiction and concerned with product evaluation that maintains periodic inspection of production of labeled equipment or materials and by whose labeling the manufacturer indicates compliance with appropriate standards or performance in a specified manner.

Listed.* Equipment or materials included in a list published by an organization acceptable to the authority having jurisdiction and concerned with product evaluation that maintains periodic inspection of production of listed equipment or materials and whose listing states either that the equipment or material meets appropriate standards or has been tested and found suitable for use in a specified manner.

Lithium. Either pure metal or alloys having the generally recognized properties of lithium metal, including the burning characteristics of lithium.

Noncombustible. In the form used and under the conditions anticipated, will not ignite, burn, support combustion, or release flammable vapors when subjected to fire or heat. (Materials reported as noncombustible, where tested in accordance with ASTM E136, *Standard Test Method for Behavior of Materials in a Vertical Tube Furnace at 750°C*, are considered noncombustible materials.)

Shall. Indicates a mandatory requirement.

Should. Indicates a recommendation or that which is advised but not required.

Chapter 2 General Precautions

2-1* Special Considerations.

Lithium shall be kept away from sources of moisture.

2-2* Handling, Processing, and Storage Areas for Lithium.

Lithium shall be handled, processed, and stored only in areas specifically suitable for the special hazards of lithium.

2-3* Lithium Fire Residue.

2-3.1*

Lithium fire residues shall be protected to prevent adverse reactions and to prevent the formation of reactive or unstable compounds.

2-3.2

Lithium fire residues shall be disposed of in accordance with federal, state, and local regulations.

2-4 Fire Inspection Frequency.

Containers of lithium fire residue shall be inspected monthly by individuals who are familiar with lithium hazards and able to recognize potential problems associated with these containers.

Chapter 3 Building Construction

3-1 General.

3-1.1

This chapter applies to buildings or portions of buildings that are dedicated to the handling or storage of solid or molten lithium.

3-1.2

Buildings dedicated to the storage, handling, processing, or use of lithium shall be constructed of noncombustible materials.

Exception: Other construction types shall be permitted if equivalent protection can be demonstrated.

3-1.3

Buildings shall comply with applicable provisions of NFPA *101®*, *Life Safety Code®*.

3-1.4*

Roof decks shall be watertight.

3-1.5

Walls and ceilings shall be constructed with noncombustible insulation tested in accordance with ASTM E136, *Standard Test Method for Behavior of Materials in a Vertical Tube Furnace at 750°C*.

3-1.6*

All floors or elevated platforms shall be sealed against the penetration of lithium. In areas where molten lithium is handled, wall-to-floor connections shall be constructed with the minimum number of joints.

3-1.7

Floor drains shall not be permitted.

3-1.8

Where molten lithium is handled, dispensed, or stored, the handling area shall be provided with a steel-lined containment. The containment shall provide for a volume of 110 percent of the maximum amount of material that is contained or could be spilled in the area. In areas where molten lithium is handled, wall-to-floor connections shall be sealed against the penetration of molten lithium.

3-1.9

All electrical equipment and wiring shall comply with NFPA 70, *National Electrical Code®*.

3-2 Separation from Water.

3-2.1

Water pipes or pipes that can contain water under normal use (e.g., domestic water, roof drains, waste pipes, etc.) shall not be permitted in areas containing lithium. Sprinkler piping shall not be permitted to pass through lithium areas for which sprinkler systems have been deemed inappropriate.

Exception: Sprinkler system piping as allowed by the Exception to 6-1.2 shall be permitted.

3-2.2

Portions of buildings shall be separated by watertight walls, ceilings, and door systems from adjacent areas not handling or storing lithium where water can be present. The floor shall be sloped away from the entrance to these areas, or other means shall be taken to prevent water from entering.

Chapter 4 Handling or Processing of Solid or Molten Lithium

4-1 General Precautions.

4-1.1

Lithium metal shall be handled only by trained personnel who are knowledgeable of the hazards associated with lithium.

4-1.2

The number of persons in lithium-handling areas during operations shall be limited to those necessary for the operation.

4-1.3

Access to lithium-handling areas by unauthorized personnel shall not be permitted.

4-1.4

Lithium shall not be handled in the presence of incompatible materials. (*See also A-5-1.3*.)

4-1.5

Primary storage of ordinary combustible materials and flammable and combustible liquids shall be prohibited in lithium-processing areas.

4-1.6

No open flames or electric or gas cutting, welding, or other spark-producing operations equipment shall be permitted in the section of the building where lithium is present unless approved hot work procedures are followed by qualified personnel. (See NFPA 51B, *Standard for Fire Prevention in Use of Cutting and Welding Processes*.)

4-1.7*

Only lithium for immediate use shall be present in handling areas. Lithium handling or processing areas shall not be used for primary storage of lithium.

4-2 Solid Lithium Handling.

4-2.1

Solid lithium shall be protected from moisture during handling by water-free mineral oil or by the use of dry air, argon, helium, or other appropriate methods.

4-2.2*

Only the amount of lithium needed for an individual task or procedure shall be removed from containers. Surplus lithium shall be returned to the shipping container and resealed as soon as possible.

4-3 Molten Lithium Handling.

4-3.1

Molten lithium shall be contained in closed systems that prevent its contact with air or reactive materials.

Exception: As required for the process.

4-3.2

Molten lithium piping systems shall be designed in conformance with ANSI B31.3, *Chemical Plant and Petroleum Refinery Piping*. All pump seals and flange gaskets shall be made of compatible materials.

4-3.3

Molten lithium systems shall overflow or relieve to secondary containments designed to handle 110 percent of the largest expected failure and shall be provided with the means to prevent contact with incompatible materials.

4-3.4

Molten lithium shall be handled in a detached building or in portions of a building separated from other exposures by barrier walls so any fire shall be permitted to be dealt with as a lithium fire.

Chapter 5 Storage of Solid or Molten Lithium

5-1 General Precautions.

5-1.1*

Lithium shall be permitted to be stored in sealed Department of Transportation (DOT) or Hazardous Materials Regulations (HM 181) approved shipping containers or in clean, moisture-free, sealed metal containers dedicated for the storage of lithium.

5-1.2

Lithium shall not be stored in containers previously used for the storage of incompatible materials.

5-1.3*

Lithium shall not be stored in an area with incompatible materials.

5-1.4

Lithium containers shall not be stored outside.

Exception: Lithium fire residues shall be permitted to be stored outside where placed in a double-steel, overpack drum and inspected daily.

5-2 Solid Lithium Storage.

5-2.1

Solid lithium shall be stored only on the ground floor. There shall be no basement or depression below the lithium storage area into which water or molten metal shall be permitted to flow or fall during a fire.

5-2.2

The solid lithium storage area shall be isolated from other areas so that water cannot enter by spray or drainage from automatic sprinkler systems or any other water source.

5-2.3 Container Storage Arrangement.

5-2.3.1 Containers shall be stored individually or on pallets in an arrangement that allows visual inspection for container integrity.

5-2.3.2 Containers on pallets shall be permitted to be stored in racks not more than 15 ft (4.5 m) high.

5-2.3.3 Containers on pallets not in racks shall not be stacked more than two high.

5-2.3.4 Aisle widths shall not be less than one-half the height of the piles.

5-2.3.5 Idle pallet storage shall not be permitted in solid lithium storage areas.

5-3 Molten Lithium Storage.

Molten lithium storage shall be in closed systems and in separate buildings or portions of buildings designed by competent designers solely for that purpose.

Chapter 6 Fire Protection

6-1* General Precautions.

6-1.1

A fire protection plan shall be provided for all areas where lithium is processed, handled, used, and stored.

6-1.2*

Buildings or portions of buildings dedicated to lithium storage or handling shall not be permitted to be equipped with automatic sprinkler protection.

Exception: Sprinkler systems installed in accordance with NFPA 13, Standard for the Installation of Sprinkler Systems, shall be permitted in areas where combustibles other than lithium create a more severe fire hazard than the lithium and where acceptable to an authority having jurisdiction who is knowledgeable of the hazards associated with lithium.

6-1.3

As an alternative, a specially engineered fire protection system specifically designed to be compatible with the hazards present in the lithium operation area shall be permitted to be installed in areas where combustible loading is essential to the process operation.

NOTE: If dry chemical extinguishing systems are used, see NFPA 17, *Standard for Dry Chemical Extinguishing Systems*.

6-2 Extinguishing Agents and Application Techniques.

6-2.1*

Only listed, Class D, extinguishing agents or those tested and shown to be effective for extinguishing lithium fires shall be permitted. A supply of extinguishing agent for manual application shall be kept within easy reach of personnel while working with lithium. The amount of extinguishing agent to be provided shall follow the listing agency's or manufacturer's recommendation.

6-2.2

Agents intended for manual application shall be kept in original labeled factory containers. Container lids shall be kept in place to prevent agent contamination and to keep agent moisture free. Where large quantities of agent are expected to be needed, a clean dry shovel shall be provided with the container. Where small amounts are needed, a hand scoop shall be provided with each container.

6-2.3*

Portable or wheeled extinguishers listed for use on lithium fires shall be permitted and shall be distributed in accordance with NFPA 10, *Standard for Portable Fire Extinguishers*.

6-2.4*

The following agents shall not be used as extinguishing agents on a lithium fire because of adverse reaction.

(a) Water,

(b) Gaseous-based foams,

(c) Halon, and

(d) Carbon dioxide.

6-2.5*

An ABC dry chemical and a B:C dry chemical extinguisher shall not be used as a lithium fire extinguishing agent, but shall be permitted to be used on other classes of fires in the area where lithium is present.

6-2.6*

Fire extinguishing agent expellant gases shall be compatible with lithium.

6-3 Personal Protective Equipment for Fire Fighting.

6-3.1*

Proper protective clothing, respiratory protection, and adequate eye protection shall be used by all responding fire-fighting personnel assigned to a lithium fire. (See NFPA 1500, *Standard on Fire Department Occupational Safety and Health Program*.)

6-3.2*

Additional eye protection shall be worn by personnel wearing SCBA protection to protect against the higher degree of emitted light during a lithium fire. Visual protection equivalent to a No. 6 welding lens shall be used.

6-4 Protective Equipment for Facility Personnel Performing Incipient Stage Lithium Fire Fighting.

6-4.1

If incipient lithium fires are to be fought, personal protective equipment shall be worn. Personal protective equipment shall include face shields, head protection, gloves, external clothing, and respiratory protection.

6-4.1.1* Personnel who attempt to fight a lithium fire in its incipient stage shall, as a minimum, wear full face shields.

6-4.1.2 Head protection shall consist of hard hats.

6-4.1.3 Gloves shall conform with 7-2.3.

6-4.1.4 If provided, external clothing shall conform with 7-2.5.

6-4.1.5 Respiratory protection suitable for the hazards of lithium shall be provided.

6-4.2

If incipient lithium fires are to be fought, personal protective equipment shall be readily accessible and maintained in good condition in all areas where lithium is handled.

6-4.3

A minimum of two sets of personal protective equipment shall be provided if incipient lithium fires are to be fought.

6-5 Lithium Fire-Fighting Procedures.

6-5.1*

While fighting a lithium fire, every effort shall be made to avoid splattering the burning lithium.

6-5.2*

Once the fire is extinguished and a crust is formed, the crust shall not be disturbed until the residues have cooled to room temperature.

Chapter 7 Personal Protective Equipment for Molten and Solid Handling Operations

7-1* Personal Protective Equipment for Solid Lithium Handling.

7-1.1

While handling solid lithium, eye protection shall be worn.

7-1.2

Gloves shall be worn while handling solid lithium. Gloves shall have tight-fitting cuffs and shall be made of a material suitable for protection from caustic hazards.

7-1.3

Clothing worn while handling solid lithium shall have no exposed pockets or cuffs that could trap and carry lithium residues.

7-2* Personal Protective Equipment for Handling Molten Lithium.

7-2.1

Personal protective equipment shall be worn and shall be compatible with the hazards of molten lithium.

7-2.2

While handling molten lithium, safety glasses and full-face protection shall be worn, i.e., face shields.

7-2.3

Gloves shall be worn and shall be loose-fitting, easily removable, and compatible with the hazards of molten lithium.

7-2.4

All clothing shall be loose-fitting, easily removable, flame-resistant, and compatible with the hazards of molten lithium.

7-2.5*

An external clothing layer shall be worn for protection from splash. The external clothing layer shall be impervious to body moisture.

7-2.6

Protective footwear shall be appropriate for the hazards of molten lithium.

Chapter 8 Referenced Publications

8-1

The following documents or portions thereof are referenced within this document and shall be considered part of the requirements of this document. The edition indicated for each reference is the current edition as of the date of the NFPA issuance of this document.

8-1.1 NFPA Publications.

National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.

NFPA 10, *Standard for Portable Fire Extinguishers*, 1994 edition.

NFPA 13, *Standard for the Installation of Sprinkler Systems*, 1994 edition.

NFPA 45, *Standard on Fire Protection for Laboratories Using Chemicals*, 1991 edition.

NFPA 70, *National Electrical Code*, 1993 edition.

NFPA *101*, *Life Safety Code*, 1994 edition.

8-1.2 ASTM Publication.

American Society for Testing and Materials, 1916 Race St., Philadelphia, PA 19103-1187.

ASTM E136, *Standard Test Method for Behavior of Materials in a Vertical Tube Furnace at 750°C*, 1993-D.

8-1.3 ANSI Publication.

American National Standards Institute, 11 West 42nd Street, New York, NY 10036.

ANSI B31.3, *Chemical Plant and Petroleum Refinery Piping*, 1993 edition.

Appendix A Explanatory Material

This Appendix is not a part of the requirements of this NFPA document but is included for informational purposes only.

A-1-1.2

Products or materials that have the characteristics of lithium should have a material safety data sheet (MSDS) that describes these burning characteristics. Refer to A-6-1, A-6-5.1, and A-6-5.2 for a general explanation of these characteristics, and consult with the manufacturer or technical personnel knowledgeable of the hazards associated with lithium.

A-1-1.6

Finely divided dry lithium and finely divided lithium dispersed in a flammable liquid can exhibit pyrophoric properties and, therefore, do not act as combustible metals, as covered by this standard.

A-1-5 Definitions.

Approved. The National Fire Protection Association does not approve, inspect, or certify any installations, procedures, equipment, or materials; nor does it approve or evaluate testing laboratories. In determining the acceptability of installations, procedures, equipment, or materials, the authority having jurisdiction may base acceptance on compliance with NFPA or other appropriate standards. In the absence of such standards, said authority may require evidence of proper installation, procedure, or use. The authority having jurisdiction may also refer to the listings or labeling practices of an organization concerned with product evaluations that is in a position to determine compliance with appropriate standards for the current production of listed items.

Authority Having Jurisdiction. The phrase “authority having jurisdiction” is used in NFPA documents in a broad manner, since jurisdictions and approval agencies vary, as do their responsibilities. Where public safety is primary, the authority having jurisdiction may be a federal, state, local, or other regional department or individual such as a fire chief; fire marshal; chief of a fire prevention bureau, labor department, or health department; building official; electrical inspector; or others having statutory authority. For insurance purposes, an insurance inspection department, rating bureau, or other insurance company representative may be the authority having jurisdiction. In many circumstances, the property owner or his or her designated agent assumes the role of the authority having jurisdiction; at government installations, the commanding officer or departmental official may be the authority having jurisdiction.

Listed. The means for identifying listed equipment may vary for each organization concerned with product evaluation, some of which do not recognize equipment as listed unless it is also labeled. The authority having jurisdiction should utilize the system employed by the listing organization to identify a listed product.

A-2-1

Lithium reacts with moisture from any available source, such as concrete, the atmosphere, and human skin. The degree and speed of the reaction varies with conditions; therefore, the best approach is to take precautions to keep moisture away from lithium.

A-2-2

Small facilities isolated from other facilities under the same ownership are ideal for handling and processing lithium. In the event of an uncontrolled lithium emergency, property damage would be considerably less.

A-2-3

Lithium fire residue products can include metallic lithium, lithium nitride, lithium oxide, or lithium hydroxide, which can absorb moisture.

A-2-3.1

Once a lithium fire is extinguished, lithium is usually still present in sufficient quantity to create adverse reactions and exhibit the burning characteristics of lithium. Lithium fire residues can include other reactive components. These residues can react with each other and cause re-ignition. Containers of residues can be purged with argon gas or the residues can be coated with water-free mineral oil to reduce the potential for reaction.

A-3-1.4

The requirement for watertight roof decks is an effort to ensure that buildings are designed and maintained to minimize possible leaks from weather conditions. Special care should be given to maintain these roofs, especially in climates where heavy amounts of snow are expected.

A-3-1.6

Nonslip surfaces should be provided due to the potential presence of mineral oil on the floor. Gratings should be used only where containment provisions have been provided below the area or where access can be restricted below the area.

A-4-1.7

When evaluating the amounts needed for immediate use, the risks and fire exposures should be evaluated with other processing requirements.

A-4-2.2

Solid lithium is supplied in a variety of forms, e.g., ingots and ribbon, which are often individually protected in small cans or airtight foil pouches. If individual containers are not supplied and the containers are opened, lithium is exposed to surrounding air, causing slow reactions to take place. It is for this reason that once the container is opened, only that amount of lithium intended to be used should be removed.

A-5-1.1

Lithium is shipped from lithium manufacturers in DOT or HM 181-approved containers that should continue to act as storage containers. Containers should be sealed to remain airtight, with lithium coated with mineral oil or packed under an argon cover. Containers used to store lithium under mineral oil for long-term storage (over three months) should be inverted to redistribute the mineral oil covering the lithium. Containers packed under an argon cover should be regularly checked to verify the integrity of the container seal. When lithium is returned to any shipping container, the protective method used by the manufacturer should be duplicated.

A-5-1.3

Lithium is known to be incompatible with the following materials: inorganic and organic acids; Halon 1211; Halon 2402; carbon tetrachloride; 1,1,1 trichloroethane; oxidizers such as nitric acid, chromic acid, phosphoric acid, or hypochlorous acid; and reducing acids such as sulfuric, hydrochloric, and sulfamic acid. Oxalic acid, phenol and organic acid mixtures, or compounds such as paint strippers or metal cleaners are also reactive and should not be stored in the vicinity of lithium. Refer to NFPA 491M, *Manual of Hazardous Chemical Reactions*.

A-6-1

Lithium fires, being quite unique in nature, require a comprehensive fire protection plan where lithium is processed, handled, used, or stored. This plan should include specific actions in the event of a lithium fire and should be coordinated with the local facility management, responding fire fighters, and medical personnel.

This plan should pay special attention to the extreme hazards associated with lithium-water reactions that might occur with sprinkler water. Specific attention should be paid to an evacuation plan for personnel in the event of any release of water.

The particulate fumes given off by burning lithium are very corrosive; therefore, nonessential personnel in the vicinity should be evacuated to a safe distance, with special attention given to shifting winds. Where frequent lithium fires can affect local environmental quality conditions, an exhaust treatment system should be provided.

Properly trained personnel who work with lithium know its hazards. Such personnel will have the greatest chance to extinguish a lithium fire in its incipient stage. Training should include sufficient information to determine if extinguishment can be safely and effectively accomplished.

Lithium at room temperature in the presence of incompatible materials can reach the melting point and reach the autoignition temperature.

The degree of reaction and the amount of time to produce these effects vary with conditions surrounding the fire; temperature of the exposed lithium being the major factor. At low temperatures or temperatures within a few degrees of lithium's melting point, the reaction is slower with reduced intensity. At higher temperatures, the reaction is accelerated and more intense.

When fighting a lithium fire, it is very important that fire fighters be aware of the dangers of burning lithium. When molten lithium reacts with materials such as water or flammable or combustible liquids or gases, molten lithium can be ejected for a considerable distance. The severity of lithium reactions varies with a multitude of conditions.

Lithium in contact with moisture and air forms lithium hydroxide and lithium oxide, which will cause caustic burns without adequate personal protective equipment.

A-6-1.2

The reaction of lithium, especially burning lithium, with water is extremely hazardous. Where combustible loading in areas used for lithium processing is determined by the authority having jurisdiction to require sprinkler protection, consideration should be given to the installation of preaction sprinkler systems to reduce the opportunity for accidental discharge.

A-6-2.1

Several agents, e.g., graphite-based agents and lith-x, have been successfully tested on lithium fires and found to be successful with varying results. These agents all form a crust of varying durability over the fuel, but due to molten lithium's fluid properties, lithium tends to seek any weak spot in this crust and develop "burn-throughs." Copper powder formed the most durable crust of all these effective fire-fighting agents.

Low density agents were found to be difficult to apply in windy conditions, resulting in decreased extinguisher effective range, reduced visibility, and larger amounts of agent needed.

Testing indicates that the amount of agent needed depends on several factors. Small-scale lithium fires require the use of an acceptable ratio of extinguishing agents. Larger fires can require dramatically larger ratios. The acceptable ratio varies, depending on the agent selected.

Lithium, with its low density, will float on solid or liquid. Extinguishing agents will tend to sink in molten lithium; therefore, as depth of fuel increases, the amount of agent needed will increase. Extended testing and evaluation of lithium fires indicates the amount of agent needed is not based on weight of agent per weight of fuel, but should be based on depth and surface area of involved fuel per weight of agent.

The lower the temperature of the lithium, the less heat will be required to be drawn from the lithium to reduce reactions, therefore reducing the amount of agent needed.

A-6-2.3

In cases where the weight of the lithium hazard is small and well defined, portable or wheeled extinguishers should be distributed so that at least one is located within 75 ft (22.7 m) of the hazard and additional extinguishers can be readily available.

The reasoning for recommending wheeled extinguishers where large amounts of lithium are found is based on the following:

(a) One or two individuals can deliver large amounts of agent in a relatively short period of time.

(b) Being highly mobile, wheeled extinguishers can be situated to provide a more complete coverage of any facility.

(c) Wheeled units protecting other areas that might not be affected in the emergency can be brought to the scene.

A-6-2.4

The following extinguishing agents should not be used as lithium fire extinguishing agents:

(a) The application of water in any form on lithium releases considerable amounts of hydrogen gas, steam, and heat and is not recommended on lithium.

Tests have demonstrated that the effect of water on lithium fires is the formation of hydrogen gas. In some cases, hydrogen will burn and intensify the fire; in other cases, hydrogen results in rapid heat rise with an explosive-like effect.

The amount of hydrogen gas present in the vicinity of any lithium reaction is directly proportional to the degree of further reaction. If the environment surrounding the fire is such that the hydrogen gas is driven off or its concentration is reduced to a level below its lower explosive limit, the reaction is less in intensity.

(b) Past testing of the application of aqueous film-forming foam (AFFF) on burning lithium resulted in extreme reactions.

(c) Halon should not be used as a lithium fire extinguishing agent.

Halon, when applied to a lithium fire, exhibits an immediate reaction. One effect is that the reaction will track the agent stream putting the fire fighter in increased danger.

(d) The application of CO_2 produces minimal reactions, yet the force of this agent can greatly spread burning lithium. Therefore, CO_2 is not recommended as a lithium fire extinguishing agent.

A-6-2.5

Dry chemical agents should not be used on a lithium fire. Testing indicated that a B:C dry chemical was not an effective lithium fire-fighting agent although it exhibited the least amount of adverse reaction with lithium.

A-6-2.6

Many common extinguishing agents and extinguisher expelling gases, when exposed to burning lithium, exhibit high reactivity. The degree of reactivity depends on a wide range of variables, e.g., temperature of the fire and other chemical compounds reacting with the lithium. For example, nitrogen commonly used to expel dry powder agent does not exhibit a high degree of reactivity until the temperature of the fire increases.

Testing has indicated that carbon dioxide and nitrogen, commonly used as extinguisher expellant gases, are reactive to lithium at higher temperatures. Argon gas, being nonreactive to lithium, can be used successfully as a substitute.

If lithium is involved in a multiclass fire and agents that are reactive to lithium, e.g., water, AFFF, and halon, are used, expect and prepare for the effects of the reaction. Use unmanned delivery techniques and use whatever physical protection is available.

A-6-3.1

Burning lithium will burn through material used in the construction of most fire fighter protective clothing. Some features (e.g., heavy quilted lining and aluminized outer shell) can reduce this risk. It is recognized that SCBA face piece eye protection worn by fire fighters is adequate protection with the exception of the intense light given off by burning lithium.

A-6-3.2

Specific testing has indicated that white light levels emitted from burning lithium exceed recommended levels. Extended lithium fire experience has shown that this intense light can cause serious damage to unprotected eyes.

A clip-on adapter over an SCBA face piece with a shaded glass lens equivalent to a No. 6 welding lens has been used very successfully to reduce such hazards. A darker lens tends to obstruct fire fighters view to an unacceptable degree.

A-6-4.1.1 Full face shields, preferably shaded shields, should be made readily available in areas where lithium fires are likely to occur. These shields will provide adequate protection against small incipient-stage lithium fires.

A-6-5.1

One of the greatest dangers to fire fighters is the splattering effect of burning lithium. Molten lithium is very fluid and easily spread; therefore, extreme care needs to be taken when applying fire-fighting agent. The force used to deliver agent from an extinguisher can easily spread lithium particles; therefore, delivery technique is very important. Should direct agent application become hazardous, indirect application techniques should be used. Deflecting agent off another object or directing the agent stream above the hazard and letting the agent fall by gravity can be effective.

A-6-5.2

Forming a crust over burning lithium reduces the available oxygen and eliminates exothermic reactions. Extinguishing agent should first be applied to the white-hot burning areas, then evenly applied to the mass, controlling the flow to form an oxygen-depleting crust. Since lithium tends to flow easily through any weak spots, agents should be applied evenly to construct a continuous crust. If lithium surfaces, additional agent should be applied to strengthen the crust.

Actual crust formation is created by the ability of some powdered agents to absorb heat from the lithium. In the case of copper powder, a lithium-copper alloy is formed as heat is absorbed from the lithium. Once the crust is formed, the temperature of the lithium decreases and exothermic reactions are reduced. Extreme care should be taken to ensure the crust is not disturbed or broken until the temperature of the lithium is decreased to the point where resolidification occurs.

A-7-1

Lithium in contact with moisture forms lithium hydroxide and lithium oxide, which will cause caustic burns. Lithium in contact with human skin will react with body moisture and cause thermal and caustic burns.

A-7-2

Hazards involved with handling molten lithium are significantly greater than those of handling solid lithium due to enhanced reactivity, heat of reaction, and elevated temperatures.

A-7-2.5

Fire risk is significantly reduced when the outer clothing layer is kept dry.

Appendix B Referenced Publications

B-1

The following documents or portions thereof are referenced within this standard for informational purposes only and thus are not considered part of the requirements of this document. The edition indicated for each reference is the current edition as of the date of the NFPA issuance of this document.

B-1.1 NFPA Publications.

National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.

NFPA 17, *Standard for Dry Chemical Extinguishing Systems*, 1994 edition.

NFPA 51B, *Standard for Fire Prevention in Use of Cutting and Welding Processes*, 1994 edition.

NFPA 491M, *Manual of Hazardous Chemical Reactions*, 1991 edition.

NFPA 1500, *Standard on Fire Department Occupational Safety and Health Program*, 1992 edition.

B-1.2 Other Publications.

B-1.2.1 ASTM Publication. American Society for Testing and Materials, 1916 Race St., Philadelphia, PA 19103-1187.

ASTM E136, *Standard Test Method for Behavior of Materials in a Vertical Tube Furnace at 750°C,* 1993-D.

B-1.2.2 New Mexico Engineering Research Institute, University of New Mexico, Albuquerque, NM 87131-1376.

Moore, T. A., Stepetic, T. J., and Tapscott, R.E., Preliminary Environmental and Safety Evaluation of Large Scale Lithium Metal Fires, Naval Undersea Warfare Engineering Station, Keyport, Washington, March 1989.

Lee, M. E., Stepetic, T. J., Watson, J. D., and Moore, T. A., Lithium Fire Suppression Study, Phase 3 (Medium-Scale), Naval Undersea Warfare Engineering Station, Keyport, Washington, November 1989. (NMERI OC 90/10).

B-1.2.3 U.S. Government Publication. U.S. Government Printing Office, Superintendent of Documents, Washington, DC 20402.

49 CFR Part 1200 (DOT and HM-181) and Parts 100-199.

B-1.2.4 National Safety Council, 1121 Spring Lake Dr., Itasca, IL, 60143-3201.

National Safety Council, Data Sheet 1-66, Lithium.

NFPA 490

1993 Edition

Code for the Storage of Ammonium Nitrate

1993 Edition

This edition of NFPA 490, *Code for the Storage of Ammonium Nitrate*, was prepared by the Technical Committee on Hazardous Chemicals and acted on by the National Fire Protection Association, Inc. at its Fall Meeting held November 16-18, 1992, in Dallas, TX. It was issued by the Standards Council on January 15, 1993, with an effective date of February 12, 1993, and supersedes all previous editions.

The 1993 edition of this document has been approved by the American National Standards Institute.

Changes other than editorial are indicated by a vertical rule in the margin of the pages on which they appear. These lines are included as an aid to the user in identifying changes from the previous edition.

Origin and Development of NFPA 490

NFPA 490 was developed by the Technical Committee on Storage, Handling, and Transportation of Hazardous Chemicals and was tentatively adopted by the Association in 1963. It was further amended and again tentatively adopted in 1964. After further revision, it was officially adopted in 1965. Amendments to NFPA 490 were adopted in 1967, 1969, and 1970. A complete revision was adopted in 1975 and several minor amendments were adopted in 1980 and 1985.

The 1993 edition of NFPA 490 incorporates amendments to the document to enhance its enforceability by revising nonmandatory language provisions and conformance with the NFPA *Manual of Style*.

Technical Committee on Hazardous Chemicals

William J. Bradford, *Chairman*
Brookfield, CT

John A. Davenport, *Vice Chairman*
Industrial Risk Insurers, CT

E. Alan Culpepper, Radian, VA

James L. Daneker, Los Angeles City Fire Dept., CA

August L. DeVico II, Handy & Harman, NJ
Rep. NFPA Industrial Fire Protection Section

Henry L. Febo, Factory Mutual Research Corp., MA

H. Dieter Heinz, Industrial Emergency Council, CA

John M. Hoffmann, Safety Engineering Labs Inc., MI

Bruce A. Jacobsen, Olin Corp., TN

Roland J. Land, Jardine Insurance Brokers, NY

Rick A. Leffel, Thiokol Inc., UT

George H. Matthews, P & G Pharmaceuticals, NY
Rep. Proctor & Gamble

Chester M. McCloskey, The Norac Co. Inc., CA

Rep. Society of the Plastics Industries Inc.

David P. Nugent, Schirmer Engineering Corp., IL

Gary A. Page, American Cyanamid Co., NJ

George W. Rambo, GRCS, Inc., VA

Richard A. Schultz, Callery Chemical Co., PA

Lynn K. Underwood, Wausau Insurance Cos., WI

Robert W. VanDolah, Pittsburgh, PA

Alternates

Chaman L. Aggarwal, Industrial Risk Insurers, CT
(Alt. to J. A. Davenport)

J. P. Carroll, Society of Plastics Industries, DC
(Alt. to C. M. McCloskey)

Paul S. Loomis, Olin Corp., CT
(Alt. to B. A. Jacobsen)

Nonvoting

Charles H. Ke, Dept. of Transportation, DC

Samuel J. Porter, Lakeridge, VA
(Member Emeritus)

Anthony Santos, Sharon, MA
(Member Emeritus)

Martha H. Curtis, NFPA Staff Liaison

This list represents the membership at the time the Committee was balloted on the text of this edition. Since that time, changes in the membership may have occurred.

NOTE: Membership on a Committee shall not in and of itself constitute an endorsement of the Association or any document developed by the Committee on which the member serves.

Committee Scope: To develop and maintain current codes for classes of hazardous chemicals and codes for specific chemicals when these are warranted by virtue of widespread distribution or special hazards.

NFPA 490

Code for the Storage of Ammonium Nitrate

1993 Edition

NOTICE: An asterisk (*) following the number or letter designating a paragraph indicates explanatory material on that paragraph in Appendix A.
Information on referenced publications can be found in Chapter 8 and Appendix D.

Foreword

Ammonium nitrate[1] is a compound containing nitrogen, hydrogen, and oxygen (NH_4NO_3) and is commercially produced by reacting nitric acid with ammonia, evaporating the resultant solution of ammonium nitrate to make a concentrated ammonium nitrate melt, which is then spray granulated in a prilling tower or pelletized or flaked by some other means.

For interstate shipments, the Department of Transportation of the United States classifies ammonium nitrate as an oxidizing material, as it does some other fertilizer products such as sodium nitrate, potassium nitrate, and calcium nitrate. Such oxidizing materials can yield oxygen upon decomposition under fire conditions and will, therefore, under proper conditions of mixing, vigorously support combustion if involved in a fire with combustible materials. Ammonium nitrate is capable of undergoing detonation with about half the blast effect of explosives, if heated under confinement that permits high pressure build-up, or if subjected to strong shocks, such as those from an explosive. The sensitivity of ammonium nitrate to detonation increases at elevated temperatures.

Industrial use of ammonium nitrate extends to its use as an ingredient in blasting agents. When a carbonaceous or organic substance such as fuel (or diesel) oil, nut hulls, or carbon black is added and admixed with ammonium nitrate, the mixture may become a blasting agent. A blasting agent is defined as being any material or mixture, consisting of a fuel and oxidizer, intended for blasting, not otherwise classed as an explosive and in which none of the ingredients is classified as an explosive, provided that the finished product, as mixed and packaged for use or shipment, cannot be detonated by means of a No. 8 test blasting cap when unconfined. (*See NFPA 495, Explosive Materials Code.*)

Recent test data on ammonium nitrate are included in the U.S. Bureau of Mines Report of Investigations 6746, *Sympathetic Detonation of Ammonium Nitrate and Ammonium Nitrate Fuel Oil*; Report of Investigations 6903, *Further Studies of Sympathetic Detonation*; and Report of Investigations 6773, *Explosion Hazards of Ammonium Nitrate Under Fire Exposure*. On the basis of these reports a Table of Distances of Ammonium Nitrate and Blasting Agents from Explosives or Blasting Agents has been developed. The table is included in Appendix C of *NFPA 495*, *Explosive Materials Code*.

While blasting agents should not be confused with fertilizer products, extreme care should be taken to ensure that stored ammonium nitrate does not become sensitized by intimate mixing with carbonaceous, organic, or combustible material.

Mixed fertilizers containing less than 60 percent ammonium nitrate are not covered by this code.

With proper precautions against fire and explosion, ammonium nitrate can be stored safely at the plant, in distributors' warehouses, or on the farm.

[1]The term is used in this publication refers only to solid forms of ammonium nitrate.

Chapter 1 Scope and Definitions

1-1 Scope.

1-1.1

This code shall apply to the storage of ammonium nitrate in the form of crystals, flakes, grains, or prills including fertilizer grade (as defined by *Definitions and Test Procedures for Ammonium Nitrate Fertilizer*), dynamite grade, nitrous oxide grade [as defined by *Standard for Ammonium Nitrate (Nitrous Oxide Grade)*], technical grade, and other mixtures containing 60 percent or more by weight of ammonium nitrate.

1-1.2

It shall not apply to the transportation of ammonium nitrate.

1-1.3

It shall not apply to storage under the jurisdiction of and in compliance with the regulations of the United States Coast Guard.

1-1.4

This code shall not apply to ammonium nitrate-based blasting agents. (*See NFPA 495, Explosive Materials Code.*)

1-1.5

The storage of ammonium nitrate and ammonium nitrate mixtures that are more sensitive than allowed by the *Definitions and Test Procedures for Ammonium Nitrate Fertilizer* shall not be permitted by this code except on the specific approval of the authority having jurisdiction.

1-1.6

Nothing in this code shall apply to the production of ammonium nitrate or to the storage of ammonium nitrate on the premises of the producing plant, provided that no distinct undue hazard to the public is created.

1-2 Purpose.

The purpose of this code is to provide for the safe storage of fertilizer grade ammonium nitrate.

1-3 Definitions.

Approved. Acceptable to the “authority having jurisdiction.”

NOTE: The National Fire Protection Association does not approve, inspect or certify any installations, procedures, equipment, or materials nor does it approve or evaluate testing laboratories. In determining the acceptability of installations or procedures, equipment or materials, the authority having jurisdiction may base acceptance on compliance with NFPA or other appropriate standards. In the absence of such standards, said authority may require evidence of proper installation, procedure or use. The authority having jurisdiction may also refer to the listings or labeling practices of an organization concerned with product evaluations which is in a position to determine compliance with appropriate standards for the current production of listed items.

Authority Having Jurisdiction. The “authority having jurisdiction” is the organization, office or individual responsible for “approving” equipment, an installation or a procedure.

NOTE: The phrase “authority having jurisdiction” is used in NFPA documents in a broad manner since jurisdictions and “approval” agencies vary as do their responsibilities. Where public safety is primary, the “authority having jurisdiction” may be a federal, state, local or other regional department or individual such as a fire chief, fire marshal, chief of a fire prevention bureau, labor department, health department, building official, electrical inspector, or others having statutory authority. For insurance purposes, an insurance inspection department, rating bureau, or other insurance company representative may be the “authority having jurisdiction.” In many circumstances the property owner or his designated agent assumes the role of the “authority having jurisdiction”; at government installations, the commanding officer or departmental official may be the “authority having jurisdiction.”

Labeled. Equipment or materials to which has been attached a label, symbol or other identifying mark of an organization acceptable to the “authority having jurisdiction” and concerned with product evaluation, that maintains periodic inspection of production of labeled equipment or materials and by whose labeling the manufacturer indicates compliance with appropriate standards or performance in a specified manner.

Listed. Equipment or materials included in a list published by an organization acceptable to the “authority having jurisdiction” and concerned with product evaluation, that maintains periodic inspection of production of listed equipment or materials and whose listing states either that the equipment or material meets appropriate standards or has been tested and found suitable for use in a specified manner.

NOTE: The means for identifying listed equipment may vary for each organization concerned with product evaluation, some of which do not recognize equipment as listed unless it is also labeled. The “authority having jurisdiction” should utilize the system employed by the listing organization to identify a listed product.

Shall. Indicates a mandatory requirement.

Should. Indicates a recommendation or that which is advised but not required.

Chapter 2 General Provisions

2-1 Application.

This code shall apply to all persons, firms, corporations, co-partnerships, and associations storing, having, or keeping ammonium nitrate and to the owner or lessee of any building, premises, or structure in which ammonium nitrate is stored in quantities of 1,000 lb (454 kg) or more.

2-2 Restricted Locations.

2-2.1

A permit shall be required from the authority having jurisdiction for the storage of 1,000 lb (454 kg) or more of ammonium nitrate.

2-2.2

Not more than 60 tons (54.4 metric tons) of ammonium nitrate shall be stored unless the location and storage facility have been approved.

2-2.3

Storage locations shall be subject to approval by the authority having jurisdiction with respect to nearness of residential occupancies, places of public assembly, schools, hospitals, railroads, and public highways. Limitations on storable quantities shall be considered with regard to proximity of these exposures and congested commercial or industrial districts.

2-2.4*

Approval of large quantity storage shall be subject to due consideration of the fire and explosion hazards, including exposure to toxic vapors from burning or decomposing ammonium nitrate.

2-3 Structures.

2-3.1

Storage buildings shall not have basements unless the basements are open on at least one side. Storage buildings shall not be over one story in height, unless approved for such use.

2-3.2

Storage buildings shall have adequate ventilation or be of a construction that will be self-ventilating in the event of fire.

2-3.3

The wall on the exposed side of a storage building within 50 ft (15.2 m) of a combustible building, forest, piles of combustible materials, and similar exposure hazards shall be of Type I construction, as described in NFPA 220, *Standard on Types of Building Construction*. In lieu of the Type I wall, other equivalent means of exposure protection such as a free standing wall shall be permitted to be used. The roof coverings shall be Class C or better. (*See NFPA 203, Guideline on Roof Coverings and Roof Deck Constructions*.)

2-3.4

All flooring in storage and handling areas shall be of noncombustible material or protected against impregnation by ammonium nitrate and shall be without open drains, traps, tunnels, pits, or pockets into which any molten ammonium nitrate could flow and be confined in the event of fire.

2-3.5

The continued use of an existing storage building or structure not in strict conformity with this code shall be approved by the authority having jurisdiction in cases where such continued use will not constitute a hazard to life or adjoining property.

2-3.6

Buildings and structures shall be dry and free from water seepage through the roof, walls, and floors.

Chapter 3 Storage of Ammonium Nitrate in Bags, Drums, or Other Containers

3-1 Containers.

3-1.1

Bags and containers used for ammonium nitrate shall comply with the specifications and standards established by the U.S. Department of Transportation.

3-1.2

Containers used on the premises in the actual manufacturing or processing need not comply with provisions of 3-1.1.

3-2 Piles.

3-2.1

Containers of ammonium nitrate shall not be accepted for storage when the temperature of the ammonium nitrate exceeds 130°F (54.4°C).

3-2.2

Bags of ammonium nitrate shall not be stored within 30 in. (76 cm) of the storage building walls and partitions.

3-2.3

The height of piles shall not exceed 20 ft (6.1 m). The width of piles shall not exceed 20 ft (6.1 m) nor the length 50 ft (15.2 m) except that, where the building is of noncombustible construction or is protected by automatic sprinklers, the length of piles shall not be limited. In no case shall the ammonium nitrate be stacked closer than 36 in. (0.9 m) below the roof or supporting and spreader beams overhead.

3-2.4

Aisles shall be provided to separate piles by a clear space of not less than 3 ft (0.9 m) in width. At least one service or main aisle in the storage area shall be not less than 4 ft (1.2 m) in width.

3-2.5

The requirements for pile sizes and aisles, as set forth in 3-2.3 and 3-2.4, shall be permitted to be waived by the authority having jurisdiction where storage facilities are located in remote areas.

Chapter 4 Storage of Bulk Ammonium Nitrate

4-1 Structures.

4-1.1

Warehouses shall have adequate ventilation or be capable of adequate ventilation in case of fire.

4-1.2

Unless constructed of noncombustible material or unless adequate facilities for fighting a roof fire are available, bulk storage structures shall not exceed a height of 40 ft (12.2 m).

4-2 Compartments.

4-2.1

Bins shall be clean and free of materials that can contaminate ammonium nitrate.

4-2.2*

Due to the corrosive and reactive properties of ammonium nitrate, and to avoid contamination, galvanized iron, copper, lead, and zinc shall not be used in bin construction unless suitably protected. Aluminum bins, and wooden bins protected against impregnation by ammonium nitrate, are permissible.

4-2.3

The warehouse shall be permitted to be subdivided into any desired number of ammonium nitrate storage compartments or bins. The partitions dividing the ammonium nitrate storage from the storage of other products that would contaminate the ammonium nitrate shall be of tight construction.

4-2.4

The ammonium nitrate storage bins or piles shall be clearly identified by signs reading “AMMONIUM NITRATE” with letters at least 2 in. (5 cm) high.

4-3 Piles.

4-3.1

Piles or bins shall be so sized and arranged that all material in the pile is moved out periodically in order to minimize possible caking of the stored ammonium nitrate.

4-3.2*

Height or depth of piles shall be limited by the pressure-setting tendency of the product. However, in no case shall the ammonium nitrate be piled higher at any point than 36 in. (0.9 m) below the roof or supporting and spreader beams overhead.

4-3.3

Ammonium nitrate shall not be accepted for storage when the temperature of the product exceeds 130°F (54.4°C).

4-3.4

Dynamite, other explosives, and blasting agents shall not be used to break up or loosen caked ammonium nitrate.

Chapter 5 Contaminants

5-1 Separation.

5-1.1

Ammonium nitrate shall be in a separate building or shall be separated by approved fire partitions of not less than 1 hour fire endurance from storage of organic chemicals, acids or other corrosive materials, materials that can require blasting during processing or handling, compressed flammable gases, flammable and combustible materials, or other contaminating substances including *but not limited to* animal fats, baled cotton, baled rags, baled scrap paper, bleaching powder, burlap or cotton bags, caustic soda, coal, coke, charcoal, cork, camphor, excelsior, fibers of any kind, fish oils, fish meal, foam rubber, hay, lubricating oil, linseed oil, or other oxidizable or drying oils, naphthalene, oakum, oiled clothing, oiled paper, oiled textiles, paint, straw, sawdust, wood shavings, or vegetable oil. Walls referred to in this section need extend only to the underside of the roof.

5-1.2

In lieu of separation walls, ammonium nitrate shall be permitted to be separated from the materials referred to in 5-1.1 by a space of at least 30 ft (9.1 m) or more as required by the authority having jurisdiction and sills or curbs shall be provided to prevent mixing during fire conditions.

5-1.3

Flammable liquids such as gasoline, kerosene, solvents, and light fuel oils shall not be stored on the premises except where such storage conforms to NFPA 30, *Flammable and Combustible Liquids Code*, and where walls and sills or curbs are provided in accordance with 5-1.1 or 5-1.2.

5-1.4

LP-Gas shall not be stored on the premises except where such storage conforms to NFPA 58, *Standard for the Storage and Handling of Liquefied Petroleum Gases*.

5-2 Prohibited Articles.

5-2.1

Sulfur and finely divided metals shall not be stored in the same building with ammonium nitrate except where such storage conforms to NFPA 495, *Explosive Materials Code*.

5-2.2

Explosives and blasting agents shall not be stored in the same building with ammonium nitrate except on the premises of makers, distributors, and user-compounders of explosives or blasting agents.

5-2.2.1 Where explosives or blasting agents are stored in separate buildings, other than on the premises of makers, distributors, and user-compounders of explosives or blasting agents, they shall be separated from the ammonium nitrate by the distances or barricades specified in the *Table of Recommended Separation Distances of Ammonium Nitrate and Blasting Agents from Explosives or Blasting Agents*, found in NFPA 495, *Explosive Materials Code.*

5-2.2.2 Storage or operations on the premises of makers, distributors, and user-compounders of explosives or blasting agents shall be in conformity with NFPA 495, *Explosive Materials Code*.

Chapter 6 General Precautions

6-1 Electrical Installations.

6-1.1

Electrical installations shall conform to the requirements of NFPA 70, *National Electrical Code,*® for ordinary locations. They shall be designed to minimize damage from corrosion.

6-1.2

Electric lamps shall be located or guarded so as to preclude contact with bags or other combustible materials.

6-2 Housekeeping.

6-2.1

Good housekeeping shall be maintained.

6-2.2

If contents of broken bags are uncontaminated, they shall be permitted to be salvaged by placing the damaged bag inside a clean, new slipover bag and closing securely. Other spilled materials and discarded containers shall be promptly gathered and disposed of in a safe manner.

6-3 Sources of Ignition.

Open flames and smoking shall be prohibited in storage buildings, and this is not meant to include heating units approved by the authority having jurisdiction.

6-4 Signs.

All points of entry to commercial warehouses in which ammonium nitrate is stored shall be properly identified with durable signs meeting the following specifications:

(a) Signs shall have background and letters in contrasting colors.

(b) Signs shall be worded “AMMONIUM NITRATE,” with letters at least 2 in. (5 cm) high.

6-5 Vehicles and Lift Trucks.

6-5.1

Internal combustion motor vehicles, lift trucks, and cargo conveyors shall not be permitted to remain unattended in a building where ammonium nitrate is stored unless parked in an area that will prevent the spreading of a fire in the event of a vehicle fire.

6-5.2*

Fork trucks, tractors, platform lift trucks, and other specialized industrial trucks used within the warehouse shall be maintained so that fuels or hydraulic fluids do not contaminate the ammonium nitrate.

6-6* Handling Equipment.

Hollow spaces shall be avoided in nitrate handling equipment where nitrate could collect and be confined under sufficiently high pressure to become a source of explosion in the event of fire.

6-7 Lightning.

In areas where lightning storms are prevalent, lightning protection shall be provided. (*See NFPA 780, Lightning Protection Code.*)

6-8 Control of Access.

Provisions shall be made to prevent unauthorized personnel from entering the ammonium nitrate storage area.

Chapter 7 Fire Protection

7-1 Automatic Sprinklers.

7-1.1

Unless the storage of a greater quantity is approved by the authority having jurisdiction, not more than 2,500 tons (2,268 metric tons) of bagged ammonium nitrate shall be stored in a building or structure not equipped with an automatic sprinkler system.

7-1.2

When determining whether greater quantities shall be permitted without sprinkler protection, the authority having jurisdiction shall take into consideration exposure of the storage building to built-up areas and possible presence of contaminants in the storage building.

7-1.3

Sprinkler protection shall be permitted to be required for the storage of less than 2,500 tons (2,268 metric tons) of ammonium nitrate where location of the building or the presence of other stored materials can present a special hazard.

7-1.4

Sprinkler systems shall be of approved type and installed in accordance with NFPA 13, *Standard for the Installation of Sprinkler Systems*.

7-2 Extinguishing Devices.

7-2.1

Suitable fire control devices such as small hose or portable extinguishers shall be provided throughout the warehouse and in the loading and unloading areas. (*See NFPA 10, Standard for Portable Fire Extinguishers, and NFPA 14, Standard for the Installation of Standpipe and Hose Systems.*)

7-2.2

Water supplies and fire hydrants shall be available in accordance with recognized good practices and as required by the authority having jurisdiction. (*See NFPA 24, Standard for the Installation of Private Fire Service Mains and Their Appurtenances.*)

7-2.3

The requirements for automatic sprinklers, water supplies, and fire hydrants set forth in 7-1.4 and 7-2.2 shall be permitted to be waived by the authority having jurisdiction where storage facilities are located in remote areas.

Chapter 8 Referenced Publications

8-1

The following documents or portions thereof are referenced within this code and shall be considered part of the requirements of this document. The edition indicated for each reference is the current edition as of the date of the NFPA issuance of this document.

8-1.1 NFPA Publications.

National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.

NFPA 13, *Standard for the Installation of Sprinkler Systems*, 1991 edition

NFPA 30, *Flammable and Combustible Liquids Code*, 1990 edition

NFPA 58, *Standard for the Storage and Handling of Liquefied Petroleum Gases*, 1992 edition

NFPA 70, *National Electrical Code*, 1993 edition

NFPA 203, *Guideline on Roof Coverings and Roof Deck Constructions*, 1992 edition

NFPA 220, *Standard on Types of Building Construction*, 1992 edition

NFPA 495, *Explosive Materials Code*, 1992 edition

8-1.2 Other Publications.

Definitions and Test Procedures for Ammonium Nitrate Fertilizer, Washington, DC, Fertilizer Institute, 1984

Standard for Ammonium Nitrate (Nitrous Oxide Grade), Arlington, VA, Compressed Gas Assn.

Appendix A Explanatory Notes

This Appendix is not a part of the requirements of this NFPA document, but is included for information purposes only.

A-2-2.4

Ammonium nitrate is capable of undergoing detonation with the blast effect of about half the quantity of explosives, if heated under confinement that permits high pressure build-up or if subjected to strong shocks, such as those from an explosive. The sensitivity of ammonium nitrate to detonation is increased by elevated temperatures or by contamination. (*See Chapter 5.*)

A-4-2.2

Steel or wood can be protected by special coatings such as sodium silicate, or epoxy coatings, or polyvinyl chloride coatings.

A-4-3.2

Pressure setting is a factor affected by humidity and temperature in the storage space and by pellet quality. Temperature cycles through 90°F (32°C) and high atmospheric humidity are undesirable for storage in depth.

A-6-5.2

It is recommended that electric or LP-Gas powered trucks be employed rather than gasoline or diesel to reduce the potential for contamination to ammonium nitrate.

A-6-6

Examples of hollow spaces include hollow conveyor rollers and hollow screw conveyor shafts.

Appendix B Suggested Fire Fighting Procedure

This Appendix is not a part of the requirements of this NFPA document, but is included for information purposes only.

B-1

Should a fire break out in an area where ammonium nitrate is stored, it is important that the mass be kept cool and the burning be promptly extinguished. Apply large volumes of water as quickly as possible. If fires reach massive and uncontrollable proportions, fire fighting personnel should evacuate the area and withdraw to a safe place.

B-2

Provide as much ventilation as possible to the fire area. Rapid dissipation of both the products of decomposition and the heat of reaction is very important.

B-3

Approach the fire from upwind as the vapors from burning ammonium nitrate are very toxic. Self-contained breathing apparatus of types approved by the U.S. Bureau of Mines should be used to protect personnel against gases.

B-4

After extinguishment of the fire, the loose and contaminated unsalvageable ammonium nitrate should be buried or dumped in water, where permissible. Any residue that cannot be removed by sweeping should be washed away with hoses. Flushing and scrubbing of all areas should be very thorough to ensure the dissolving of all residue. Wet empty bags should be removed, permitted to dry out, and then burned out of doors.

Appendix C Suggested Provisions for Municipal Legal Regulations

This Appendix is not a part of the requirements of this NFPA document, but is included for information purposes only.

NOTE: Where this code is used as the basis for municipal legal regulations, the following provisions are suggested as an aid to enforcement.

C-1 Title.

This ordinance shall be known as "an ordinance regulating the storage, having, and keeping of ammonium nitrate in the City of...," and shall be permitted to be referred to as "The Ammonium Nitrate Storage Ordinance."

NOTE: The title should conform with local law and practice.

C-2 Definitions.

C-2.1

Chief. The Chief of the Fire Department or his or her authorized representative is hereby designated as "the authority having jurisdiction" wherever that expression appears in the ordinance.

C-2.2 Jurisdiction.

"Jurisdiction" wherever used in this ordinance shall mean the City of...

C-2.3 Permit.

The term "Permit," wherever used in this ordinance, shall mean the written authority of the .... issued pursuant to this ordinance to store, have, or keep pure, fertilizer, or other grades of ammonium nitrate and mixtures containing 60 percent or more by weight of ammonium nitrate and that are classified as oxidizing materials (usually by the Department of Transportation) by the authority having jurisdiction.

C-3 Application.

This ordinance shall apply to all persons, firms, corporations, co-partnerships, governmental agencies except federal, and associations storing, having, or keeping ammonium nitrate and to the owner or lessee of any building or premises in or on which ammonium nitrate is stored or kept.

C-4 Permitted Locations.

C-4.1

The storage of ammonium nitrate in quantities of 1,000 lb (454 kg) or more is prohibited within the following limits:

NOTE: These limits are to be specified according to local zoning ordinances. They should include all residential, mercantile, and other congested districts.

C-4.2

No permit shall be issued until approval has been given for the proposed storage location with respect to nearness to places of public assembly, schools, hospitals and churches, and adequacy of water supply for fire control.

C-5 Retroactivity.

The chief may issue a permit for the continued use of an existing warehouse, storage facility, handling equipment, building, and structure for the storage of ammonium nitrate that is not in strict compliance with the terms of this ordinance in cases in which continued use will not constitute a distinct hazard to life or adjoining property. In cases where such permit is denied, the chief shall notify the applicant and specify the reasons for denial in writing.

C-6 Permits.

C-6.1

A permit issued pursuant to this ordinance shall be obtained from the chief to store, have, or keep, in quantities of 1,000 lb (454 kg) or more, pure, fertilizer, and other grades of ammonium nitrate, and mixtures containing 60 percent or more by weight of ammonium nitrate and that are classified as oxidizing materials (usually by the Department of Transportation) by the authority having jurisdiction.

C-6.2

Permits shall not be transferable.

C-6.3

Each permit granted by the chief shall be valid for such period as may be specified but not to exceed one year, shall be a revocable license, and shall expire when revoked.

C-7 Inspection and Approval.

C-7.1

Application for a permit to use or operate facilities for the storage, having, or keeping of ammonium nitrate as herein required shall be made in writing to the chief. The chief shall then cause to be made an inspection of the premises and equipment proposed to be used. If they are found to be in compliance with this ordinance, a statement to that effect shall be noted on the application and the application signed by the person making the inspection. The chief shall thereupon issue a permit as applied for.

C-7.2

The chief may at any reasonable time inspect premises, buildings, installations, or equipment for the storage and handling of ammonium nitrate. If a violation of this ordinance is found to exist, the chief shall file with the owner, occupant, or operator a notice citing the violation and ordering its correction. If such order is not complied with, the chief may suspend the permit issued for such facility.

C-7.3

In the event that an inspection reveals a violation of this ordinance serious enough in the chief's opinion to constitute a clear and present danger to the public safety, the chief shall take whatever measures are necessary to correct, abate, or remove the hazard or condition.

C-8 Modification.

The chief shall have the power to grant exemption from application of the ordinance upon request in writing to do so when such request shows that the enforcement of the ordinance will cause unnecessary hardship to the petitioner, provided that said request shall not be granted where the requested use will constitute a distinct hazard to life or adjoining property. The particulars of such exemptions when granted shall be entered upon the permit issued. A copy thereof shall be retained by the chief.

C-9 Appeals.

C-9.1

An owner, lessee, agent, operator, or occupant aggrieved by any order issued pursuant to this ordinance may file an appeal to the City Council within ten days from the service of such an order, and the City Council shall fix a time and place not less than five days nor more than ten days thereafter when and where such appeal may be heard by it. Such appeal shall stay the execution of such order until it has been heard and reviewed, vacated, or confirmed. Nothing in this section shall be construed as preventing the chief from taking any action indicated by Section B-7-3 of this ordinance.

NOTE: This section should conform to local law and practice with respect to terminology and designation of agency to hear appeals.

C-9.2

The City Council shall at such hearing affirm, modify, revoke, or vacate such order. Unless revoked or vacated, such order shall then be complied with.

C-9.3

Nothing therein contained shall be deemed to deny the right of any person, firm, corporation, co-partnership, or voluntary association to appeal from an order or decision of the City Council to a court of competent jurisdiction. Such appeal shall stay the execution of such order until it has been heard and reviewed, vacated, or confirmed.

C-10 Penalties.

Any person who shall violate any of the provisions of this ordinance or fail to comply therewith, or who shall violate or fail to comply with any order made thereunder, or who shall build in violation of any detailed statement of specifications or plans submitted and approved thereunder, or any certificate or permit issued thereunder, and from which no appeal has been taken, or who shall fail to comply with such an order as affirmed or modified by the City Council or by a court of competent jurisdiction, within the time fixed herein shall severally for each and every violation and non-compliance, respectively, be guilty of a misdemeanor, punishable by a fine of not less than $..................... or by imprisonment for not less than............... days nor more than............ days or by both such fine and imprisonment. The imposition of one penalty for any violation shall not excuse the violation or permit it to continue; and all such persons shall be required to correct or remedy such violations or defects within a reasonable time; and when not otherwise specified, each ten days that prohibited conditions are maintained shall constitute a separate offense. The application of the foregoing penalty shall not be held to prevent the enforced removal of prohibited conditions.

C-11 Repeal of Conflicting Ordinances.

All former ordinances or parts thereof conflicting with the provisions of this ordinance are hereby repealed.

C-12 Severability.

The City Council hereby declares that, should any section, paragraph, sentence, or word of this ordinance be declared, for any reason, to be invalid, it is the intent of said City Council that it would have passed all other portions of this ordinance independent of the elimination herefrom of any such portion as may be declared invalid.

C-13 Effective Date.

This ordinance shall take effect upon .... of ....

Appendix D Referenced Publications

D-1

The following documents or portions thereof are referenced within this code for informational purposes only and thus should not be considered part of the requirements of this document. The edition indicated for each reference is the current edition as of the date of the NFPA issuance of this document.

D-1.1 NFPA Publications.

National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.

NFPA 10, *Standard for Portable Fire Extinguishers*, 1990 edition

NFPA 14, *Standard for the Installation of Standpipe and Hose Systems*, 1993 edition

NFPA 24, *Standard for the Installation of Private Fire Service Mains and Their Appurtenances*, 1992 edition

NFPA 780, *Lightning Protection Code*, 1992 edition

D-1.2 Other Publications.

D-1.2.1 U.S. Government Publications. U.S. Bureau of Mines, Pittsburgh Mining and Safety Research Center, 4800 Forbes Ave., Pittsburgh, PA 15213.

Report of Investigations 6746, *Sympathetic Detonation of Ammonium Nitrate and Ammonium Nitrate-Fuel Oil*, 1966

Report of Investigations 6773, *Explosion Hazards of Ammonium Nitrate Under Fire Exposure*, 1966

Report of Investigations 6903, *Further Studies on Sympathetic Detonation*, 1966

NFPA 491M

1991 Edition

Manual of Hazardous Chemical Reactions

1991 Edition

This edition of NFPA 491M, *Manual of Hazardous Chemical Reactions*, was prepared by the Technical Committee on Hazardous Chemical Reactions and acted on by the National Fire Protection Association, Inc. at its Fall Meeting held November 12-14, 1990 in Miami, FL. It was issued by the Standards Council on January 11, 1991, with an effective date of February 8, 1991, and supersedes all previous editions.

The 1991 edition of this document has been approved by the American National Standards

Institute.

Origin and Development of NFPA 491M

This manual was prepared by the Technical Committee on Hazardous Chemical Reactions. It has been approved for publication by the Technical Committee on Hazardous Chemical Reactions. This 1991 edition is a reconfirmation of the 1986 edition, originally published in 1975, and includes over 3500 entries of hazardous or potentially hazardous chemical reactions. As further information on hazardous reactions is accumulated, the Committee plans to publish revised editions. Those who know of references to reactions not included or who have personal knowledge of hazardous reactions are requested to send the information to the Committee Secretary, using the tear sheets at the end of the manual.

Technical Committee on Hazardous Chemical Reactions

Foreword

This manual had its beginnings in an extensive literature survey conducted by the late George W. Jones of the U.S. Bureau of Mines. For many years, Mr. Jones served as a member of the National Fire Protection Association Committee on Chemicals and Explosives and as Chairman of the closely allied American Chemical Society Committee on Hazardous Chemicals and Explosives. His untimely death prevented him from putting the compilation into final form. Subsequently, the Sectional Committee on Hazardous Chemical Reactions reviewed his compilation and arranged the format published as the first edition in 1964. The 1966 edition incorporated the remainder of Mr. Jones' compilation plus corrections and contributions from readers of the first edition and gleanings from recent literature. With more than 300 additional reactions from technical literature and individual contributions added in 1968, another 350 added in 1971, and approximately 1,200 added in 1975, this edition contains approximately 3,550 documented reactions.

The purpose of the manual is to bring to chemists and other users of chemicals a compilation of recorded experience with chemical reactions that have potential for danger. Thus, the abstracts presented here range from reactions that produce incandescence or flame at moderate or slightly elevated temperatures to those that produce explosions or detonations. In presenting the compilation at this time, the Committee fully recognizes certain inadequacies and possible inaccuracies but hopes the manual's shortcomings will not seriously impair its usefulness. Since some of the information was obtained from very old references, its validity may be questioned; many of the reported hazardous reactions may have been due to impurities or contaminants in the materials involved. At the same time, the user should be cautioned that the absence of a reaction from this listing in no way implies that combinations of materials may be mixed with impunity with or without heating. Similarly, the comments that may be appended to particular reactions regarding their violence should be tempered by consideration of quantities involved, temperatures, confinement, and many other factors.

For convenience many potentially hazardous reaction mixtures have been brought together into groups. For example, the reactions of mixtures of inorganic perchlorates with many fuels can be quite violent. This association of different reactants in the same group should not be taken, however, as an indication that all such related compounds will react with equal rates or ease with a given fuel, that the violence will be equivalent in every case, or that potential contaminants, such as moisture, will have the same effect. The reader is warned that trace quantities of contaminants acting as catalysts may have a profound effect on the course and rate of the reaction. Unless there is unusual reactivity with air, oxygen, or water, the usual combustion reactions involving these oxidants have not been included for all possible fuel substances. Finally, any mixture of oxidizing and reducing agents should be suspected of being able to undergo a hazardous reaction.

Organization of this Manual

In this alphabetic tabulation, the reactions are presented in the following format:

PRIMARY ENTRY

Secondary Entries	Remarks and literature references.

Thus, the entry

ALUMINUM

Sodium Carbonate	When sodium carbonate was applied to redhot aluminum, an explosion occurred.Price and Baker, *Chem. & Met. Eng.* **29:** 878 (1923).

means that aluminum and sodium carbonate react under the conditions stated and that the reference can be consulted for possible additional information. At the end of the manual, the full titles of the abbreviated names of references are listed.

This same reaction will also appear alphabetically under “sodium carbonate” as a cross-entry in bold-faced capital letters on the left margin as follows:

SODIUM CARBONATE

Aluminum	See ALUMINUM plus Sodium Carbonate.

The reactant under which the specific remarks are made (the Primary Entry) is chosen under an arbitrary system of priorities. Generally, the primary entry was selected from the higher on the following list:

CHEMICAL	*EXAMPLE*
Metallic Elements	Magnesium
Other Elements	Bromine
Classes of Compounds	Nitrates
Uncommon Compounds	Cesium Acetylene Carbide
Specific Compounds of a Class	Ammonium Nitrate
Common Acids	Nitric Acid
Common Bases	Sodium Hydroxide
Common Organic Compounds	Ethyl Alcohol
Nonchemical Names	Organic Matter

Additional guides for finding reactions in the manual are listed below:

1. When two chemical compounds are of equal importance, the first in alphabetic listing has usually received priority as the primary entry.

2. Most of the secondary entries appear also as primary cross-entries; exceptions are air, water, common chemical names like alcohol and ether, and trivial or common names like caustic soda or wood. For these common substances, refer to the other reactant or to the specific chemical name. Since so many reactions concern charcoal, this material is a primary entry.

3. For some common organic chemicals, popular names were used in preference to scientific nomenclature; for example, methyl bromide, rather than monobromomethane.

4. A chemical name is used in preference to its creator’s name, thus, permonosulfuric acid, rather than Caro’s acid.

5. A few proprietary names appear in preference to the relatively unknown chemical identification of the compound, e.g., Teflon® instead of polytetrafluoroethylene.

6. If no hazardous reaction is listed for a particular pair of chemicals, the reader should look up possible reactions between chemicals with similar properties. For example, if no reaction is given between cesium and hydrochloric acid, see sodium and hydrochloric acid. The violence of

the reaction between the similar chemicals may not be the same, but the combination should be regarded as suspect.

7. The manual does not list explosive fuel-air mixtures, but does list pyrophoric or hypergolic (self-igniting) mixtures.

8. The manual also lists a number of individual chemicals that explode or detonate spontaneously or in response to impact or heat. In such cases the chemical is listed as the primary entry, under which is printed the term, “self-reactive.”

9. A number of entries by “families” of chemicals, e.g., nitrates, sulfates, aldehydes, ethers, are included to facilitate the search for reactions. Frequently, these entries cross-refer to reactions of individual chemicals of the family.

10. Isomeric designations such as “iso” and “n” do not affect the alphabetic arrangement of chemical names in this manual.

REFERENCES

An effort has been made to furnish references complete enough to lead the reader to the source of information. At the end of the manual, the full titles are listed for the abbreviated names of references that accompany the reactions. If a statement about a reaction might disclose proprietary information, the source is protected by the reference, “Confidential information furnished to NFPA.”

INFORMATION ON ERRORS AND OMISSIONS WELCOMED

The Technical Committee on Hazardous Chemical Reactions will welcome comments on and criticisms of the present compilation. If a reader can cite more up-to-date references or experiences concerning any of the listed reactions, the information also will be welcomed. Similarly, the Committee would very much appreciate receiving brief details of incidents involving hazardous chemical reactions not yet included in the manual, so that these can be compiled and included in a later revision. Such material should be transmitted to Guy R. Colonna, Secretary, Committee on Chemicals and Explosives, National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101. Tear-out pages for forwarding new material are at the back of the manual.

NFPA 491M

Manual of Hazardous Chemical Reactions

1991 Edition

ACETALDEHYDE CH_3CHO

Acetic Acid	Acetaldehyde was put in drums previously pickled with acetic acid. The acid caused the acetaldehyde to polymerize, and the drums became hot and vented. *MCA Case History* **1764** (1971).
Acid Anhydrides	Condensation reaction of acetaldehyde with acid

	anhydrides, alcohols, ketones, and phenols can be violent.
	Chem. Safety Data Sheet **SD-43** (1952).
Air	Acetaldehyde oxidizes readily in air to unstable peroxides that may explode spontaneously.
	Chem. Safety Data Sheet **SD-43** (1952).
Alcohols	See ACETALDEHYDE plus Acid Anhydrides.
	Chem. Safety Data Sheet **SD-43** (1952).
Ammonia (Anhydrous)	Reaction of anhydrous ammonia, hydrogen cyanide, or hydrogen sulfide can be violent.
	Chem. Safety Data Sheet **SD-43** (1952).
Bromine	See BROMINE plus Acetaldehyde.
Chlorine	See CHLORINE plus Acetaldehyde.
Fluorine	See BROMINE plus Acetaldehyde.
Hydrogen Cyanide	See ACETALDEHYDE plus Ammonia (Anhydrous).
Hydrogen Sulfide	See ACETALDEHYDE plus Ammonia (Anhydrous).
Iodine	See BROMINE plus Acetaldehyde.
Ketones	See ACETALDEHYDE plus Acid Anhydrides.
Phenols	See ACETALDEHYDE plus Acid Anhydrides.
Phosphorus Isocyanate	See PHOSPHORUS ISOCYANATE plus Acetaldehyde.
Sodium Hydroxide	A violent polymerization of acetaldehyde results from reactions with alkaline materials such as sodium hydroxide.
	Doyle (1966).

ACETIC ACID CH_3COOH

Acetaldehyde	See ACETALDEHYDE plus Acetic Acid.
2-Aminoethanol	Mixing acetic acid and 2-aminoethanol in a closed container caused the temperature and pressure to increas e.
	Flynn and Rossow (1970). See Note under complete reference.

Ammonium Nitrate	See AMMONIUM NITRATE plus Acetic Acid.
Bromine Pentafluoride	See BROMINE PENTAFLUORIDE plus Acetic Acid.
Chlorine Trifluoride	See CHLORINE TRIFLUORIDE plus Acetic Acid.
Chlorosulfonic Acid	Mixing glacial acetic acid and chlorosulfonic acid in a closed container caused the temperature and pressure to increase.
	Flynn and Rossow (1970). See Note under complete reference.
Chromic Acid	See CHROMIC ANHYDRIDE plus Acetic Acid.
Chromic Anhydride	See CHROMIC ANHYDRIDE plus Acetic
and Acetic Anhydride	Acid and Acetic Anhydride.
Diallyl Methyl	See DIALLYL METHYL CARBINOL plus
Carbinol and Ozone	Ozone and Acetic Acid.
Ethylene Diamine	Mixing acetic acid and ethylene diamine in a closed container caused the temperature and pressure to increase.
	Flynn and Rossow (1970). See Note under complete reference.
Ethyleneimine	Mixing glacial acetic acid and ethyleneimine in a closed container caused the temperature and pressure to increase.
	Flynn and Rossow (1970). See Note under complete reference.
Hydrogen Peroxide	See HYDROGEN PEROXIDE plus Acetic Acid.
Nitric Acid	See NITRIC ACID plus Acetic Acid.
Nitric Acid and	See NITRIC ACID plus Acetone and Acetic
Acetone	Acid.
Oleum	Mixing glacial acetic acid and oleum in a closed container caused the temperature and pressure to increase.
	Flynn and Rossow (1970). See Note under complete reference.
Perchloric Acid	See PERCHLORIC ACID plus Acetic Acid.
Permanganates	See PERMANGANATES plus Acetic Acid.

Phosphorus Isocyanate	See PHOSPHORUS ISOCYANATE plus Acetaldehyde.
Phosphorus Trichloride	See PHOSPHORUS TRICHLORIDE plus Acetic Acid.
Potassium Hydroxide	Potassium hydroxide residue in a catalyst pot reacted violently when acetic acid was added. *MCA Case History* **920** (1963).
Potassium Tert.-Butoxide	See ACETONE plus Potassium Tert.-Butoxide.
Sodium Hydroxide	See SODIUM HYDROXIDE plus Acetic Acid.
Sodium Peroxide	See SODIUM PEROXIDE plus Acetic Acid.
n-Xylene	During the production of terephthalic acid, n-xylene is oxidized in the presence of acetic acid. During these processes, detonating mixtures may be produced. Addition of a small amount of water may largely eliminate the risk of explosion. B.I. Sraer, *Himiceskaja promyslennost* **46** (10): 27-30 (1970).

ACETIC ANHYDRIDE $CH_3COOCOCH_3$

2-Aminoethanol	Mixing acetic anhydride and 2-aminoethanol in a closed container caused the temperature and pressure to increase. *Flynn and Rossow* (1970). See Note under complete reference.
Aniline	See ANILINE plus Acetic Anhydride.
Boric Acid	See BORIC ACID plus Acetic Anhydride.
Chlorosulfonic Acid	Mixing acetic anhydride and chlorosulfonic acid in a closed container caused the temperature and pressure to increase. *Flynn and Rossow* (1970). See Note under complete reference.
Chromic Acid	See CHROMIC ANHYDRIDE plus Acetic Anhydride.
Chromic Anhydride	See CHROMIC ANHYDRIDE plus Acetic Anhydride.
Chromic Anhydride and Acetic Acid	See CHROMIC ANHYDRIDE plus Acetic Anhydride and Acetic Acid.

Ethylene Diamine	Mixing acetic anhydride and ethylene diamine in a closed container caused the temperature and pressure to increase.
	Flynn and Rossow (1970). See Note under complete reference.
Ethyleneimine	Mixing acetic anhydride and ethyleneimine in a closed container caused the temperature and pressure to increase.
	Flynn and Rossow (1970). See Note under complete reference.
Glycerol	A violent reaction occurs between these reactants in the presence of phosphorus oxychloride as a catalyst.
	Hexagon Alpha Chi Sigma **40** (Oct. 1949).
Hydrochloric Acid	Mixing acetic anhydride and 36% hydrochloric acid in a closed container caused the temperature and pressure to increase.
	Flynn and Rossow (1970). See Note under complete reference.
Hydrofluoric Acid	Mixing acetic anhydride and 48.7% hydrofluoric acid in a closed container caused the temperature and pressure to increase.
	Flynn and Rossow (1970). See Note under complete reference.
Hydrogen Peroxide	See HYDROGEN PEROXIDE plus Acetic Acid.
Nitric Acid	Mixing acetic anhydride and 70% nitric acid in a closed container caused the temperature and pressure to increase.
	Flynn and Rossow (1970). See Note under complete reference.
	See NITRIC ACID plus Acetic Anhydride.
	See NITRIC ACID plus Acetic Acid.
Nitrogen Tetroxide	See NITROGEN TETROXIDE plus Acetic Anhydride.
Oleum	Mixing acetic anhydride and oleum in a closed container caused the temperature and pressure to increase.
	Flynn and Rossow (1970). See Note under complete reference.

Perchloric Acid	See PERCHLORIC ACID plus Acetic Acid.
	See PERCHLORIC ACID plus Acetic Anhydride.
Permanganates	See PERMANGANATES plus Acetic Acid.
Sodium Hydroxide	See SODIUM HYDROXIDE plus Acetic Anhydride.
Sodium Peroxide	See SODIUM PEROXIDE plus Acetic Acid.
Sulfuric Acid	Mixing acetic anhydride and 96% sulfuric acid in a closed container caused the temperature and pressure to increase.
	Flynn and Rossow (1970). See Note under complete reference.
Water	The mixing of acetic anhydride with water can be dangerously explosive, especially when mineral acids are present.
	Chem. Eng. News **25:** 3458.

ACETONE CH_3COCH_3

Chloroform	A mixture of acetone and chloroform in a residue bottle exploded. Since addition of chloroform to acetone in the presence of a base will result in a highly exothermic reaction, it is thought that a base may have been in the bottle.
	MCA Case History **1661** (1970).
Chromic Anhydride	See CHROMIC ANHYDRIDE plus Acetone.
Chromyl Chloride	See CHROMYL CHLORIDE plus Acetone.
Hexachloromelamine	See HEXACHLOROMELAMINE plus Organic Contaminants.
Hydrogen Peroxide	See HYDROGEN PEROXIDE plus Organic Matter.
Nitric Acid and Acetic Acid	See NITRIC ACID plus Acetone and Acetic Acid.
Nitric Acid and Sulfuric Acid	See NITRIC ACID plus Acetone and Sulfuric Acid.

Nitrosyl Chloride	See NITROSYL CHLORIDE plus Acetone.
Nitrosyl Perchlorate	See NITROSYL PERCHLORATE plus Acetone.
Nitryl Perchlorate	See NITRYL PERCHLORATE plus Benzene.
Permonosulfuric Acid	See PERMONOSULFURIC ACID plus Acetone.
Potassium Tert.-Butoxide	Ignition occurs when potassium t-butoxide reacts with the following: acetone, ethyl methyl ketone, methyl isobutyl ketone, methanol, ethanol, n-propanol, isopropanol, ethyl acetate, n-butyl acetate, n-propyl formate, acetic acid, sulfuric acid, methylene chloride, chloroform, carbon tetrachloride, epichlorohydrin, dimethyl carbonate, and diethyl sulfate.
	MCA Case History **1948** (1973).
Sodium Hypobromite	An explosion occurred during an attempt to prepare bromoform from acetone by the haloform reaction.
	Chem. Eng. News **9:** 229 (1931).
Sulfuric Acid and Potassium	Acetone ignited when it was accidentally
Dichromate	splashed into a sulfuric acid-dichromate solution.
	Wischmeyer (1969).
Thiodiglycol and	See THIODIGLYCOL plus Hydrogen Peroxide
Hydrogen Peroxide	and Acetone.
Trichloromelamine	See HEXACHLOROMELAMINE plus Organic Contaminants.

ACETONE CYANHYDRIN

(See a-HYDROXYISOBUTYRONITRILE)

ACETONITRILE CH_3CN

Chlorosulfonic Acid	Mixing acetonitrile and chlorosulfonic acid in a closed container caused the temperature and pressure to increase.
	Flynn and Rossow (1970). See Note under complete reference.

Erbium Perchlorate	In the preparation of anhydrous erbium perchlorate an acetonitrile extraction was made. During the final stages of the procedure a glossy material was formed that exploded when scratched with a spatula. It was concluded that acetonitrile was trapped in the glossy erbium perchlorate and that this material was shock-sensitive as are many organic-containing perchlorates.
	J. Chem. Edu. **50** (6): A336-7 (1973).
Oleum	Mixing acetonitrile and oleum in a closed container caused the temperature and pressure to increase.
	Flynn and Rossow (1970). See Note under complete reference.
Sulfuric Acid	Mixing acetonitrile and 96% sulfuric acid in a closed container caused the temperature and pressure to increase.
	Flynn and Rossow (1970). See Note under complete reference.

ACETYL BROMIDE CH_3COBr

Alcohols	Acetyl bromide reacts violently with alcohols or water.
	Merck Index **7th Ed.** (1960).
Water	See ACETYL BROMIDE plus Alcohols.

ACETYL CHLORIDE CH_3COCl

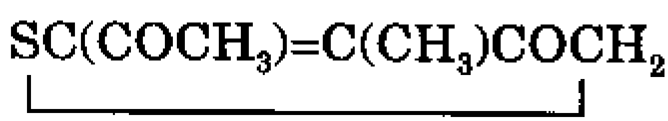
Dimethyl Sulfoxide	See DIMETHYL SULFOXIDE plus Acyl Halides.
Ethyl Alcohol	Acetyl chloride reacts violently with ethyl alcohol or water.
	Rose (1961).
Water	Acetyl chloride reacts violently with water.
	Haz. Chem. Data (1966).

ACETYLENE $CH\equiv CH$

Brass	See COPPER plus Acetylene.

Bromine	See BROMINE plus Acetylene.
Cesium Hydride	See CESIUM HYDRIDE plus Acetylene.
Chlorine	See CHLORINE plus Acetylene.
Cobalt	See COBALT plus Acetylene.
Copper	See COPPER plus Acetylene.
Copper Salts	See COPPER SALTS plus Acetylene.
Cuprous Acetylide	See CUPROUS ACETYLIDE plus Acetylene.
Fluorine	See FLUORINE plus Acetylene.
Iodine	See IODINE plus Acetylene.
Mercuric Nitrate	See MERCURIC NITRATE plus Acetylene.
Mercury	See MERCURY plus Acetylene.
Mercury Salts	See MERCURY SALTS plus Acetylene.
Nitric Acid	See NITRIC ACID plus Acetylene.
Potassium	See POTASSIUM plus Acetylene.
Rubidium Hydride	See RUBIDIUM HYDRIDE plus Acetylene.
Silver	See SILVER plus Acetylene.
Silver Salts	See MERCURY SALTS plus Acetylene.
	See also SILVER NITRATE plus Acetylene and Ammonium Hydroxide.
Sodium Hydride	See SODIUM HYDRIDE plus Acetylene.

2-ACETYL-3-METHYLTHIOPHEN-4-ONE



(self-reactive) — A vacuum distillation of 2-acetyl-3-methylthiophen-4-one was being performed on a laboratory bench when suddenly

	there was an explosion.
	MCA Guide for Safety, Appendix 3 (1972).

ACETYL NITRATE CH_3COONO_2

(self-reactive)	Acetyl nitrate has been reported to explode during vacuum distillation; also, when touched by a glass rod.
	J. P. Wilaut, *Chem. Zentr.* **112**(I):384 (1943).
	Pichet and Khotinsky, *Berichte* **40**:1164 (1907).

ACETYL PEROXIDE

(See DIACETYL PEROXIDE)

ACID ANHYDRIDES

(See specific Anhydride)

Acetaldehyde	See ACETALDEHYDE plus Acid Anhydrides.

ACIDS

(See also specific acid)

Acrolein	See ACROLEIN plus Sulfur Dioxide.
Benzyl Alcohol	Benzyl alcohol containing acidic constituents and dissolved iron was found to polymerize with a rapid temperature increase when heated in excess of 100¡C. Amines, pyridene, and alkali hydroxides act as inhibitors and prevent polymerization.
	Chem. Abst. **77**:7816w (1972).
Lithium Aluminum	See LITHIUM ALUMINUM HYDRIDE
Hydride	plus Water.
Nickel Nitride	See NICKEL NITRIDE plus Acids.
Sodium Ozonate	See SODIUM OZONATE plus Acids.

Thorium Phosphide	See THORIUM PHOSPHIDE plus Acids.
Tri-iso-Butyl Aluminum	See TRI-iso-BUTYL ALUMINUM plus Acids.

ACROLEIN CH_2=CHCHO

Acids	See ACROLEIN plus Sulfur Dioxide.
Alkalis	See ACROLEIN plus Sulfur Dioxide.
Amines	See ACROLEIN plus Sulfur Dioxide.
	See SODIUM HYDROXIDE plus Acrolein.
2-Aminoethanol	Mixing acrolein and 2-aminoethanol in a closed container caused the temperature and pressure to increase.
	Flynn and Rossow (1970). See Note under complete reference.
Ammonia	See SODIUM HYDROXIDE plus Acrolein.
Ammonium Hydroxide	Mixing acrolein and 28% ammonium hydroxide in a closed container caused the temperature and pressure to increase.
	Flynn and Rossow (1970). See Note under complete reference.
Chlorosulfonic Acid	Mixing acrolein and chlorosulfonic acid in a closed container caused the temperature and pressure to increase.
	Flynn and Rossow (1970). See Note under complete reference.
Ethylene Diamine	Mixing acrolein and ethylene diamine in a closed container caused the temperature and pressure to increase.
	Flynn and Rossow (1970). See Note under complete reference.
Ethyleneimine	Mixing acrolein and ethyleneimine in a closed container caused the temperature and pressure to increase.
	Flynn and Rossow (1970). See Note under complete reference.
Hydroxides	See SODIUM HYDROXIDE plus Acrolein.

Nitric Acid	Mixing acrolein and 70% nitric acid in a closed container caused the temperature and pressure to increase. *Flynn and Rossow* (1970). See Note under complete reference.
Oleum	Mixing acrolein and oleum in a closed container caused the temperature and pressure to increase. *Flynn and Rossow* (1970). See Note under complete reference.
Potassium Hydroxide	See SODIUM HYDROXIDE plus Acrolein.
Sodium Hydroxide	See SODIUM HYDROXIDE plus Acrolein.
Sulfur Dioxide	Acrolein polymerizes with release of heat on contact with minor amounts of acids (including sulfur dioxide), alkalis, volatile amines, salts, thiourea, oxidants (air) and on exposure to light and heat. *BCISC* **44**:174 (1973).
Sulfuric Acid	Mixing acrolein and 96% sulfuric acid in a closed container caused the temperature and pressure to increase. *Flynn and Rossow* (1970). See Note under complete reference.
Thiourea	See ACROLEIN plus Sulfur Dioxide.

ACRYLIC ACID $H_2C{=}CHCOOH$

2-Aminoethanol	Mixing acrylic acid and 2-aminoethanol in a closed container caused the temperature and pressure to increase. *Flynn and Rossow* (1970). See Note under complete reference.
Ammonium Hydroxide	Mixing acrylic acid and 28% ammonium hydroxide in a closed container caused the temperature and pressure to increase. *Flynn and Rossow* (1970). See Note under complete reference.
Chlorosulfonic Acid	Mixing acrylic acid and chlorosulfonic acid in a closed container caused the temperature and pressure to increase.

	Flynn and Rossow (1970). See Note under complete reference.
Ethylene Diamine	Mixing acrylic acid and ethylene diamine in a closed container caused the temperature and pressure to increase.
	Flynn and Rossow (1970). See Note under complete reference.
Ethyleneimine	Mixing acrylic acid and ethyleneimine in a closed container caused the temperature and pressure to increase.
	Flynn and Rossow (1970). See Note under complete reference.
Oleum	Mixing acrylic acid and oleum in a closed container caused the temperature and pressure to increase.
	Flynn and Rossow (1970). See Note under complete reference.

ACRYLONITRILE CH_2=CHCN

Acids (Strong)	See ACRYLONITRILE plus Sulfuric Acid and Water.
2-Aminoethanol	Mixing acrylonitrile and 2-aminoethanol in a closed container caused the temperature and pressure to increase.
	Flynn and Rossow (1970). See Note under complete reference.
Bromine	See BROMINE plus Acrylonitrile.
Chlorosulfonic Acid	Mixing acrylonitrile and chlorosulfonic acid in a closed container caused the temperature and pressure to increase.
	Flynn and Rossow (1970). See Note under complete reference.
Ethylene Diamine	Mixing acrylonitrile and ethylene diamine in a closed container caused the temperature and pressure to increase.
	Flynn and Rossow (1970). See Note under complete reference.
Nitric Acid	Acrylonitrile and 70% Nitric Acid detonates at 90¡ C.
	Flynn and Rossow (1970). See Note under complete

	reference.
Oleum	Mixing acrylonitrile and oleum in a closed container caused the temperature and pressure to increase. *Flynn and Rossow* (1970). See Note under complete reference.
Potassium Hydroxide	See SODIUM HYDROXIDE plus Acrylonitrile.
Sodium Hydroxide	See SODIUM HYDROXIDE plus Acrylonitrile.
Sulfuric Acid	A mixture with concentrated sulfuric acid must be kept well chilled; otherwise, a vigorous exothermic reaction occurs. *Chem. Safety Data Sheet* **SD-31:** 8 (1949). A vigorous reaction between acrylonitrile and strong acids occurs with hydroquinone and powdered copper as catalysts. In the preparation of acrylic acid from these ingredients, using concentrated sulfuric acid, an eruption will occur in the flask, due to a strong exothermic reaction, unless the ingredients are kept well chilled. F. J. Kaszuba, *Chem. Eng. News* **30:** 824 (1952). Mixing acrylonitrile and 96% sulfuric acid in a closed container caused the temperature and pressure to increase. *Flynn and Rossow* (1970). See Note under complete reference.
1,2,3,4-Tetrahydrocarbazole	See 1,2,3,4-TETRAHYDROCARBAZOLE plus Acrylonitrile.

ACRYLONITRILE-BUTADIENE COPOLYMER

$[-CH_2CH=CHCH_2CH_2CH(CN)-]n$

Fluorine	See FLUORINE plus Solid Nonmetals and Oxygen.

ACYL HALIDES

Dimethyl Sulfoxide	See DIMETHYL SULFOXIDE plus Acyl Halides.

ACYL HYPOFLUORITES

(self-reactive)	See PERFLUOROPROPIONYL FLUORIDE plus Fluorine.

AIR

(See other reactant)

AIR (LIQUID)

Charcoal	Explosions have occurred when liquid air contacts organic matter. A cracked tube of activated charcoal immersed in liquid air exploded violently.
	J. Taylor, *J. Sci. Instr.* **5:** 24 (1928).
Diethyl Ether	See DIETHYL ETHER plus Air (Liquid).
Hydrocarbons	Almost any reducing agent and all hydrocarbons can form explosive mixtures with liquid air.
	Chem. Eng. News **27:** 2612 (1949).

ALCOHOLS

Acetaldehyde	See ACETALDEHYDE plus Acid Anhydrides.
Barium Perchlorate	See BARIUM PERCHLORATE plus Alcohols.
Chlorine	See ALCOHOLS plus Hypochlorous Acid.
Diethyl Aluminum Bromide	See DIETHYL ALUMINUM BROMIDE plus Air.
Ethylene Oxide	See ETHYLENE OXIDE plus Alcohols.
Hexamethylene Diiosocyanate	See ALCOHOLS plus Isocyanates.
Hydrogen Peroxide and Sulfuric Acid	Mixtures of alcohols with concentrated sulfuric acid and strong hydrogen peroxide can cause explosions. Examples: An explosion will occur if dimethylbenzylcarbinol is added to 90% hydrogen peroxide

	and then acidified with concentrated sulfuric acid. Mixtures of ethyl alcohol with concentrated hydrogen peroxide form powerful explosives. Mixtures of hydrogen peroxide and 1-phenyl-2-methyl propyl alcohol tend to explode if acidified with 70% sulfuric acid.
	Chem. Eng. News **45** (43): 73 (1967). *J. Org. Chem.* **28:** 1893 (1963).
Hypochlorous Acid	Alkyl hypochlorites are violently explosive. They are readily obtained by reacting hypochlorous acid and alcohols either in aqueous solution or in mixed water-carbon tetrachloride solutions. Obviously CHLORINE plus Alcohols would similarly produce alkyl hypochlorites. They decompose in the cold and explode on exposure to sunlight or heat. Tertiary hypochlorites are less unstable than secondary or primary hypochlorites.
	Whitmore, 157 (1937). *Mellor*, **Supp. II, Part I:** 560 (1956).
Isocyanates	Base-catalyzed reactions of isocyanates such as hexamethylene diisocyanate with alcohols should generally be carried out in inert solvents. Such reactions in the absence of solvents often occur with explosive violence.
	Wischmeyer (1969).
Lithium Aluminum Hydride	See LITHIUM ALUMINUM HYDRIDE plus Water.
Nitrogen Tetroxide	See NITROGEN TETROXIDE plus Alcohols.
Perchloric Acid	See PERCHLORIC ACID plus Alcohols.
Permonosulfuric Acid	See PERMONOSULFURIC ACID plus Alcohols.
Tri-iso-Butyl Aluminum	See TRI-iso-BUTYL ALUMINUM plus Acids.

ALDEHYDES

(See specific aldehyde plus other reactant)

ALKALI CARBONATES

Silicon	See SILICON plus Alkali Carbonates.

ALKALI HYDROXIDES

Zirconium	See ZIRCONIUM plus Alkali Hydroxides.

ALKALI METAL CHROMATES

Zirconium	See ZIRCONIUM plus Alkali Metal Salts.

ALKALI METAL DICHROMATES

Zirconium	See ZIRCONIUM plus Alkali Metal Salts.

ALKALI METAL MOLYBDATES

Zirconium	See ZIRCONIUM plus Alkali Metal Salts.

ALKALI METALS

Boron Trifluoride	Boron trifluoride reacts with incandescence when heated with alkali metals or alkaline earth metals, except magnesium.
	Merck Index, p. 163 (1960).
Hydrazine and	See HYDRAZINE plus Alkali Metals and
Ammonia	Ammonia.
Maleic Anhydride	Maleic anhydride decomposes explosively in the presence of alkali metals.
	Chem. Safety Data Sheet **SD-88** (1962).
	Chem. Haz. Info. Series **C-71** (1960).

ALKALI METAL SULFATES

Zirconium	See ZIRCONIUM plus Alkali Metal Salts.

ALKALI METAL TUNGSTATES

Zirconium	See ZIRCONIUM plus Alkali Metal Salts.

ALKALINE EARTH METALS

Boron Trifluoride	See ALKALI METALS plus Boron Trifluoride.

ALKENES

Fluorine	See FLUORINE plus Alkenes.

ALKYL AZIDES

(self-reactive)	Low molecular weight alkyl azides and diazido alkanes are considered to be particularly dangerous in the absence of suitable precautions. Introduction of more than one azide group into the molecule increases its instability. *Chem. Eng. News* **42** (31): 6 (1964).

ALKYL BENZENES

Fluorine	See FLUORINE plus Alkyl Benzenes.

ALKYLISOTHIOUREA SALTS

Chlorine	See CHLORINE plus Alkylisothiourea Salts.

ALKYLPHOSPHINES

Chlorine	See CHLORINE plus Alkylphosphines.

ALLENE $H_2C{=}C{=}CH_2$

(self-reactive)	Pure allene can decompose explosively at two atmospheres. *Rutledge*, p. 13 (1968).

ALLYL ALCOHOL CH_2=CHCH$_2$OH

Carbon Tetrachloride	A reaction between allyl alcohol and carbon tetrachloride produces trichlorobutylene epoxide (oxide) and dichlorobutylene epoxide (oxide), a mixture which during distillation proved to be unstable and detonated in the still. *Doyle* (1969).
Chlorosulfonic Acid	Mixing allyl alcohol and chlorosulfonic acid in a closed container caused the temperature and pressure to increase. *Flynn and Rossow* (1970). See Note under complete reference.
Diallyl Phosphite and Phosphorus Trichloride	See DIALLYL PHOSPHITE plus Allyl Alcohol and Phosphorus Trichloride.
Nitric Acid	Mixing allyl alcohol and 70% nitric acid in a closed container caused the temperature and pressure to increase. *Flynn and Rossow* (1970). See Note under complete reference.
Oleum	Mixing allyl alcohol and oleum in a closed container caused the temperature and pressure to increase. *Flynn and Rossow* (1970). See Note under complete reference.
Sodium Hydroxide	As a benzene extract of allyl benzenesulfonate was prepared from allyl alcohol and benzene sulfonyl chloride in the presence of aqueous sodium hydroxide, under vacuum distillation two fractions came off, then the temperature rose to 135¡C, when the residue darkened and exploded. W.T. Dye, and G.E. Ham, *Chem. Eng. News* **28:**3452 (1950). This reaction was almost certainly a caustic-catalyzed

	polymerization of allyl alcohol.
	Doyle (1966).
Sulfuric Acid	Mixing allyl alcohol and 96% sulfuric acid in a closed container caused the temperature and pressure to increase.
	Flynn and Rossow (1970). See Note under complete reference.
Tri-n-Bromomelamine	These compounds exploded fifteen minutes after mixing at room temperature.
	Chem. Eng. News **30:**1916 (1952).

ALLYL BENZENESULFONATE $CH_2{=}CHCH_2OSO_2C_6H_5$

(self-reactive)	During distillation of crude allyl benzenesulfonate, from which the benzene solvent had been removed, two fractions came off — the first at 86-92¡C and the second at 92-135¡C — then the remaining residue darkened, thickened, and exploded probably owing to uncontrolled polymerization.
	Chem. Eng. News **28:**3452 (1950).

ALLYL CHLORIDE $CH_2{=}CHCH_2Cl$

Aluminum Chloride	See SULFURIC ACID plus Allyl Chloride.
Benzene and Diethyl Aluminum Chloride	See ALLYL CHLORIDE plus Benzene and Ethyl Aluminum Dichloride.
Benzene and Ethyl Aluminum Dichloride	It has been found that allyl chloride or other alkyl halides will react vigorously with benzene or toluene, even at minus 70¡C, in the presence of ethyl aluminum dichloride or ethyl aluminum sesquichloride. Explosions have been reported.
	Wischmeyer (1970).
Benzene and Ethyl Aluminum Sesquichloride	See ALLYL CHLORIDE plus Benzene and Ethyl Aluminum Dichloride.
Chlorosulfonic Acid	Mixing allyl chloride and chlorosulfonic acid in a closed

	container caused the temperature and pressure to increase.
	Flynn and Rossow (1970). See Note under complete reference.
Ethylene Diamine	Mixing allyl chloride and ethylene diamine in a closed container caused the temperature and pressure to increase.
	Flynn and Rossow (1970). See Note under complete reference.
Ethyleneimine	Mixing allyl chloride and ethyleneimine in a closed container caused the temperature and pressure to increase.
	Flynn and Rossow (1970). See Note under complete reference.
Ferric Chloride	See SULFURIC ACID plus Allyl Chloride.
Lewis-Type Catalysts	See SULFURIC ACID plus Allyl Chloride.
Nitric Acid	Mixing allyl chloride and 70% nitric acid in a closed container caused the temperature and pressure to increase.
	Flynn and Rossow (1970). See Note under complete reference.
Oleum	Mixing allyl chloride and oleum in a closed container caused the temperature and pressure to increase.
	Flynn and Rossow (1970). See Note under complete reference.
Sodium Hydroxide	See SODIUM HYDROXIDE plus Allyl Chloride.
Sulfuric Acid	Mixing allyl chloride and 96% sulfuric acid in a closed container caused the temperature and pressure to increase.
	Flynn and Rossow (1970). See Note under complete reference.
	See SULFURIC ACID plus Allyl Chloride.
Toluene and Diethyl Aluminum Chloride	See ALLYL CHLORIDE plus Benzene and Ethyl Aluminum Dichloride.
Toluene and Ethyl Aluminum Dichloride	See ALLYL CHLORIDE plus Benzene and Ethyl Aluminum Dichloride.

Toluene and Ethyl Aluminum Sesquichloride	See ALLYL CHLORIDE plus Benzene and Ethyl Aluminum Dichloride.
Ziegler-Type Catalysts	See SULFURIC ACID plus Allyl Chloride.

ALLYLDIMETHYLARSINE $CH_2CHCH_2AS(CH_3)_2$

Air	Dimethylallylarsine ignites in air and on filter paper.
	Ellern, pp. 24, 25 (1968).

ALUMINUM Al

Ammonium Nitrate	A mixture of aluminum powder and ammonium nitrate can be used as an explosive. A number of explosions in which ammonium nitrate and aluminum are mixed with carbon, hydrocarbons, with or without oxidizing agents, have occurred.
	Mellor **5:** 219 (1946-1947).
Ammonium Persulfate	A mixture of aluminum powder with ammonium persulfate powder and water may cause an explosion.
	Pieters, p. 30 (1957).
Antimony Trichloride	See ALUMINUM plus Phosphorus Trichloride.
Arsenic Trichloride	See ALUMINUM plus Phosphorus Trichloride.
Barium Bromate	See ALUMINUM plus Bromates.
Barium Chlorate	See ALUMINUM plus Bromates.
Barium Iodate	See ALUMINUM plus Bromates.
Barium Sulfate	See ALUMINUM plus Sulfates.
Bismuth Trioxide	When bismuth trioxide is heated with powdered aluminum, the reduction occurs with explosive violence.
	Mellor **9:** 649 (1946-1947). *Ellern*, pp. 244, 280 (1968).
Bromates	A combination of finely divided aluminum with finely divided bromates (also chlorates or iodates) of barium, calcium, magnesium, potassium, sodium, or zinc can be

	exploded by heat, percussion, and sometimes, light friction.
	Mellor **2:** 310 (1946-1947).
Bromine	Bromine vapor reacts with warm aluminum foil with brilliant incandescence. The reaction is vigorous, even at 15¡C.
	Chem. News **121:** 178 (1920).
	Mellor **1:** 135 (1946-1947).
	Mellor **5:** 209 (1946-1947).
Calcium Bromate	See ALUMINUM plus Bromates.
Calcium Chlorate	See ALUMINUM plus Bromates.
Calcium Iodate	See ALUMINUM plus Bromates.
Calcium Sulfate	See ALUMINUM plus Sulfates.
Carbon Disulfide	Powdered aluminum burns in the vapor of carbon disulfide, sulfur dioxide, sulfur dichloride, nitrous oxide, nitric oxide, or nitrogen peroxide.
	Mellor **5:** 209-212 (1946-1947).
Carbon Tetrachloride	A bomb containing powdered aluminum and carbon tetrachloride exploded violently when heated to 153¡C.
	C.C. Clogston, *UL Bull. Research* **34** (1945).
	A mixture of powdered aluminum and carbon tetrachloride in a ball mill exploded.
	Chem. Eng. News **32:** 258 (1954).
	Impact sensitivity tests have shown that mixtures of carbon tetrachloride and aluminum will detonate.
	ASESB Pot. Incid. **39** (1968).
Chlorates	See ALUMINUM plus Bromates.
Chlorinated Hydrocarbons	When hot vapors contact powdered aluminum, an explosion results.
	Tech. Ind. Fire & Expl. Hazards **2:** 26 (1947).
Chlorine	Aluminum powder burns in chlorine, even at 20¡C.

Mellor **2:** 92; **5:** 209 (1946-1947).

Chlorine Trifluoride

In the presence of carbon, the combination of chlorine trifluoride with aluminum, copper, lead, magnesium, silver, tin or zinc results in a violent reaction.

Mellor **2, Supp. 1:** (1956).

See also CHLORINE TRIFLUORIDE plus Elements.

Chlorofluorohydrocarbons

It has been experimentally determined that mixtures of powdered aluminum with monofluorotrichloroethane or with trifluorotrichloroethane will flash or spark on heavy impact.

ASESB Pot. Incid. **39** (1968).

See also ALUMINUM plus Dichlorodifluoromethane.

Chloroform

Chloroform, methyl chloride, and carbon tetrachloride, and mixtures of these chemicals explode when in contact with aluminum powder or magnesium powder.

C.C. Clogston, *UL Bull. Research* **34:**5 (1945).

Chromic Anhydride

A violent reaction or flaming is likely in the reaction of chromic anhydride and aluminum powder.

Mellor **11:**237 (1946-1947).

Copper Oxide

A strong explosion occurred when aluminum was heated with copper oxide. With lead oxide, the crucible was broken to pieces and the doors of the furnace were blown off.

Mellor **5:**217-19 (1946-1947). *Ellern*, pp. 244, 280 (1968).

Diborane

Diborane reacts spontaneously with aluminum and lithium to form hydrides that ignite in air.

Haz. Chem. Data (1966).

Dichlorodifluoromethane

Destruction of the impellers in a centrifugal compressor occurred when abrasion exposed and heated fresh aluminum surfaces. These surfaces and dichlorodifluoromethane joined in a self-sustaining reaction with sufficient heat generation to melt and react much of the aluminum impeller material. Similar results were obtained in large test compressors using monochlorodifluoromethane. Follow-up laboratory test

	reactions between aluminum and (a) 1,1,2-trichloro-1,2,2-trifluoroethane; (b) monofluorotrichloromethane; (c) 1,2-dichloro-1,1,2,2-tetrafluoroethane; (d) dichlorodifluoromethane; (e) monobromotrifluoromethane; (f) monochlorodifluoromethane; (g) tetrafluoromethane established that vigorous reactions and heat outputs occurred in all cases. The vigor of the reactions and heat outputs increased in the given order, and were dependent on the combined effects of vapor pressure and degree of fluorination.
	B. J. Eiseman, Jr., *ASHRAE Journal* **5:**63 (1963). C.C. Clogston, *UL Bull. Research* **34** (1945). *Chem. Eng. News* **39** (27):44 (1961);**39** (32): 4 (1961).
1,2-Dichloro-1,1,2,2-tetrafluoroethane	See ALUMINUM plus Dichlorodifluoromethane.
Ethylene Dichloride, Propylene Dichloride, and Orthodichlorobenzene	Orthodichlorobenzene had been mixed with ethylene dichloride and propylene dichloride. This mixture dissolved the oxide coating from the aluminum containing vessel. Subsequent reaction between the aluminum vessel and the chlorinated olefins caused rupture of the vessel.
	Doyle (1966).
Fluorine	See FLUORINE plus Metals.
Fluorochloro-lubricants	An explosive reaction occurs with fluorochloro oils or greases in contact with fresh aluminum surfaces under high loads. Examples cited: a spinning aluminum rod under pressure on an aluminum surface; a freshly bored aluminum cylinder under pressure from an aluminum piston; threading an aluminum rod into a dural tube with a fluorochloro oil as a lubricant.
	Laccabue (1958).
Iodates	See ALUMINUM plus Bromates.
Iodine	Aluminum powder and iodine in close contact will ignite spontaneously.
	Ellern, p. 46 (1968).

Iodine Monochloride	Aluminum foil, after continued contact with iodine monochloride, ignites spontaneously and burns with a bluish-white flame.
	Mellor **2:** 119 (1946-1947).
Iron Oxide	The reaction of powdered aluminum and iron oxide, usually started by burning magnesium, proceeds vigorously, with evolution of intense heat. The mixture is known as "thermite."
	Mellor **5:** 217-19 (1946-1947).
	The reaction can be initiated by impact between an aluminum object and a rusty surface.
	Morse (1966). *Abbey* (1964). *Health & Safety Inf.* **161** (1963).
Lead Oxides	The reduction of lead oxide by aluminum is violent. See also ALUMINUM plus Copper Oxide.
	Mellor **7:** 658 (1946-1947). *Ellern*, pp. 244, 280 (1968).
Magnesium and Potassium Perchlorate	There have been three industrial explosions involving a photoflash composition containing potassium perchlorate with aluminum and magnesium powders.
	ACS **146:** 210. *BM Info. Circ.* **7349** (1945).
Magnesium Bromate	See ALUMINUM plus Bromates.
Magnesium Chlorate	See ALUMINUM plus Bromates.
Magnesium Iodate	See ALUMINUM plus Bromates.
Manganese and Air	See MANGANESE plus Aluminum and Air.
Methyl Bromide	Methyl bromide in a steel tank reacted with an aluminum tube (part of a level gage) producing methyl aluminum bromide. When the latter was subsequently exposed to air, enough heat was produced to ignite the methyl bromide-compressed air mixture above the liquid level. The ensuing explosion shattered the tank.
	Chem. Eng. Progr. **58** (8): 46-9 (1962).
Methyl Chloride	Methyl chloride in the presence of a small amount of

	aluminum chloride will attack powdered aluminum, forming spontaneously flammable (in air) aluminum trimethyl.
	C. C. Clogston, *UL Bull. Research* **34** (1945).
	See also ALUMINUM plus Chlorinated Hydrocarbons.
Monobromotrifluoromethane	See ALUMINUM plus Dichlorodifluoromethane.
Monochlorotrifluoromethane	See ALUMINUM plus Dichlorodifluoromethane.
Monofluorotrichloromethane	See ALUMINUM plus Dichlorodifluoromethane.
Niobium Oxide	A mixture of aluminum, niobium oxide and
and Sulfur	sulfur caused a serious fire.
	Poole (1971).
Nitrate-Nitrite and	Aluminum and aluminum alloys contaminated
Organic Matter	with organic matter are likely to explode in nitrate-nitrite salt baths.
	Pieters, p. 30 (1957).
Nitrates	Two explosions occurred in mixtures containing aluminum dust, nitrates, water, sulfur, and vegetable glues.
	Chem. Eng. News **32:** 258 (1954).
Nitric Oxide	See ALUMINUM plus Carbon Disulfide.
Nitrogen Peroxide	See ALUMINUM plus Carbon Disulfide.
Nitrosyl Chloride	Aluminum is attacked by nitrosyl chloride when cold.
	Mellor **5:** 212 (1946-1947).
Nitrous Oxide	See ALUMINUM plus Carbon Disulfide.
Oxygen	Flash bulbs containing aluminum foil plus oxygen, when ignited, cause similar bulbs up to 8 inches away to be ignited by radiated heat.
	W. Zimmerman, *Naturwissenschaften* **18:** 857 (1930).
	Liquid oxygen gives a detonable mixture when combined with powdered aluminum.
	Kirschenbaum (1956).

	A lecturer was demonstrating the ignition of powdered aluminum mixed with liquid oxygen when the mixture exploded. Seventeen persons were injured. This experiment, which is described in several places as a lecture demonstration, has been carried out successfully hundreds of times but there have been a few explosions when the conditions were just right.
	Chem. Eng. News **35**(25): 90 (June 17, 1957).
Palladium	If an aluminum sheath surrounding a palladium core of about .0025-inch diameter is heated to the melting point of aluminum, 600¡C, an alloying reaction takes place with production of a brilliant flash and a temperature of 2,800¡C.
	Tricon (1965). *Woodcock* (1967). *U.S. Pat. Gaz.,* p. 224 (Nov. 3, 1959). *Ellern,* p. 279 (1968).
Performic Acid	Powdered aluminum decomposes performic acid violently.
	Berichte **48:**1139 (1915).
Phosgene	See ALUMINUM plus Phosphorus Trichloride.
Phosphorus Trichloride	Powdered aluminum burns in the vapor of phosphorus trichloride, antimony trichloride, arsenic trichloride, and phosgene.
	Mellor **5:**214 (1946-1947).
Potassium Bromate	See ALUMINUM plus Bromates.
Potassium Chlorate	See ALUMINUM plus Bromates.
Potassium Iodate	See ALUMINUM plus Bromates.
Potassium Sulfate	See ALUMINUM plus Sulfates.
Propylene Dichloride	An aluminum transfer line failed completely after only a few hours' service in refined propylene dichloride under hot weather conditions. Following this failure, a time sequence study illustrated the nature and rapidity with which this reaction may occur.
	Chem. Abst. **52:**7986h (1958). *Corrosion* **14:** 186t-190t (1958).
Silicon and Lead Oxide	See SILICON plus Aluminum and Lead Oxide.
Silver Chloride	A reaction between silver chloride and aluminum, once

	started, proceeds with explosive violence.
	Mellor **3:**402 (1946-1947).
Sodium Bromate	See ALUMINUM plus Bromates.
Sodium Carbide	See MERCURY plus Sodium Carbide.
Sodium Carbonate	When sodium carbonate was applied to red-hot aluminum, an explosion occurred.
	Price and Baker, *Chem. & Met. Eng.* **29:**878 (1923).
Sodium Chlorate	See ALUMINUM plus Bromates.
Sodium Hydroxide	A 25 per cent sodium hydroxide solution was filtered into a tank trailer thought to be made of mild steel. By the time it was discovered that the tank was made of aluminum, copious volumes of hydrogen were already boiling off.
	MCA Case History **1115** (1965).
	Aluminum reacts vigorously in sodium hydroxide.
	Mellor **5:**207 (1946-1947).
Sodium Iodate	See ALUMINUM plus Bromates.
Sodium Peroxide	A mixture of sodium peroxide and aluminum powder reacts with incandescence. The mixture explodes when heated to redness. When the mixture is exposed to moist air, spontaneous ignition occurs.
	Mellor **2:**490; **5:**217 (1946-1947).
Sodium Peroxide and	When carbon dioxide gas is passed over a
Carbon Dioxide	mixture of powdered aluminum and sodium peroxide, the mixture explodes.
	Mellor **2:**490 (1946-1947).
Sodium Sulfate	See ALUMINUM plus Sulfates.
Sulfates	Violent explosions occur when potassium sulfate and sodium sulfate are melted with aluminum.
	Chem. Eng. News **32:** 258 (1954).
	The reduction of barium sulfate and of calcium sulfate by aluminum is attended by violent explosions.

	Mellor **5:**217-19 (1946-1947).
Sulfur Dichloride	See ALUMINUM plus Carbon Disulfide.
Sulfur Dioxide	See ALUMINUM plus Carbon Disulfide.
Tetrafluoromethane	See ALUMINUM plus Dichlorodifluoromethane.
Trichloroethylene	In the presence of dilute hydrochloric acid (0.1-0.2%) aluminum and trichloroethylene formed aluminum chloride, which catalyzed polymerization of the trichloroethylene with a very high release of heat. Under this condition subsequent oxidation of aluminum fines caused an explosion.
	J. van Hints, *Veiligheid* **28:**121-23 (1952).
	Fire and Accident Prev. (Dec. 22, 1953).
1,1,2-Trichloro-1,2,2-trifluoroethane	See ALUMINUM plus Dichlorodifluoromethane.
Zinc Bromate	See ALUMINUM plus Bromates.
Zinc Chlorate	See ALUMINUM plus Bromates.
Zinc Iodate	See ALUMINUM plus Bromates.
Zinc Peroxide	Zinc peroxide explodes when heated to about 212¡C; and when mixed with aluminum powder or zinc powder, it burns with a dazzling light.
	Mellor **4:**530 (1946-1947).

ALUMINUM AMINOBOROHYDRIDES

Air	Oily aluminum borohydrides are spontaneously flammable in air and are attacked by water.
	A. B. Burg and C. L. Randolph, Jr., *J. Am. Chem. Soc.* **73:**953 (1951).
Water	See ALUMINUM AMINOBOROHYDRIDES plus Air.

ALUMINUM BOROHYDRIDE

(See ALUMINUM TETRAHYDROBORATE)

ALUMINUM BROMIDE $AlBr_3$

Potassium	See POTASSIUM plus Aluminum Bromide.
Sodium	See SODIUM plus Aluminum Bromide.

ALUMINUM CARBIDE Al_4C_3

Lead Peroxide	Aluminum carbide reduces lead peroxide with incandescence.
	Mellor **5:**872 (1946-1947).
Potassium Permanganate	Aluminum carbide reduces potassium permanganate with incandescence.
	Mellor **5:**872 (1946-1947).

ALUMINUM CHLORIDE $AlCl_3$

(self-reactive)	After long storage of aluminum chloride in closed containers, an explosion often occurs when the container is opened.
	Chem. Abst. **41:**6723d (1947).
Allyl Chloride	See SULFURIC ACID plus Allyl Chloride.
Ethylene	Ethylene in the presence of aluminum chloride may undergo a violent reaction.
	Waterman, *J. Inst. Pet.* **33:**254 (1947).
Ethylene Oxide	See ETHYLENE OXIDE plus Aluminum Oxide.
	See ETHYLENE OXIDE plus Acids and Bases.
Nitrobenzene and Phenol	Aluminum chloride added to nitrobenzene containing about 5% phenol caused a violent explosion.
	Chem. Eng. News **31:**4915 (1953).
Nitromethane and Organic Matter	Mixtures of nitromethane and aluminum chloride may explode when organic matter is present.

	Chem. Eng. News **26:**2257 (1948).
Oxygen Difluoride	See OXYGEN DIFLUORIDE plus Aluminum Chloride.
Perchloryl Fluoride and Benzene	See PERCHLORYL FLUORIDE plus Benzene and Aluminum Chloride.
Potassium	See POTASSIUM plus Aluminum Bromide.
Sodium	See SODIUM plus Aluminum Bromide.
Water	When water was added to sublimed anhydrous aluminum chloride, a very vigorous reaction with a release of much heat and toxic hydrogen chloride resulted.
	Scott (1966).
	This salt dissolves in water with hissing and much heat.
	Mellor **5:**314 (1946-1947).

ALUMINUM FLUORIDE Alf$_3$

Potassium	See POTASSIUM plus Aluminum Bromide.
Sodium	See SODIUM plus Aluminum Bromide.

ALUMINUM HYDRIDE AlH_3

Air	Aluminum hydride will burn violently in air.
	Lab. Govt. Chemist (1965).
Dimethyl Ether	Occasional explosions involving these materials have been traced to carbon dioxide impurity in the ether.
	J. Am. Chem. Soc. **70:**877 (1948).
Oxygen	See OXYGEN plus Aluminum Hydride.

ALUMINUM HYDROXIDE $Al(OH)_3$

Bismuth	See BISMUTH plus Aluminum Hydroxide.

ALUMINUM HYPOPHOSPHITE Al $(PH_2O_2)_3$

Air	Aluminum hypophosphite releases spontaneously flammable phosphine at about 220¡C. *Mellor* **8, Supp. 3:**623 (1971).

ALUMINUM OXIDE Al_2O_3

Chlorine Trifluoride	See CHLORINE TRIFLUORIDE plus Aluminum Oxide.
Ethylene Oxide	See ETHYLENE OXIDE plus Aluminum Oxide. See ETHYLENE OXIDE plus Acids and Bases.

ALUMINUM PHOSPHIDE AlP

Water	Aluminum phosphide yields phosphine on reaction with water. Phosphine is spontaneously flammable in air. *Merck Index,* pp. 46, 823 (1968).

ALUMINUM SESQUIBROMIDE DIALUMINUM

(See TRIBROMOTRIETHOXYDIALUMINUM)

ALUMINUM TETRAAZIDOBORATE $Al[B(N_3)_4]_3$

(self-reactive)	This compound is very explosive on shock. *Mellor* **8, Supp. 2:** 2 (1967).

ALUMINUM TETRAHYDROBORATE $Al(BH_4)_3$

Air	Oily liquid aluminum borohydrides are spontaneously flammable in air; the reaction is violent with air containing moisture. *Gaylord,* p. 8 (1956). *Pease,* p. 1 (1950). H.I. Schlesinger et al., *J. Am. Chem. Soc.* **75:**210-211 (1953).

Oxygen	See OXYGEN plus Aluminum Borohydride.
Water	Aluminum borohydride will flame when in contact with water.
	Ellern, p. 45 (1968).

ALUMINUM TRIETHYL

(See TRIETHYL ALUMINUM)

ALUMINUM TRIMETHYL

(See TRIMETHYL ALUMINUM)

ALUMINUM TRIPHENYL $(C_6H_5)_3Al$

(See TRIPHENYL ALUMINUM)

ALUMINUM TRIPROPYL

(See TRIPROPYL ALUMINUM)

AMINE PERCHOLORATES

(self-reactive)	There are a large number of amine perchlorates that ignite or explode at temperatures above 215¡C.
	J. Chem. Soc. **115:** 1006-10 (1909).
	Analyst **80:** 4-15 (1955). *ACS* **146:** 211.

AMINES RNH_2

Acrolein	See ACROLEIN plus Sulfur Dioxide.
	See SODIUM HYDROXIDE plus Acrolein.
Calcium Hypochlorite	See CALCIUM HYPOCHLORITE plus Amines.
Maleic Anhydride	See SODIUM HYDROXIDE plus Maleic Anhydride.

Nitrosyl Perchlorate	See NITROSYL PERCHLORATE plus Amines.
Sodium Hypochlorite	See CALCIUM HYPOCHLORITE plus Amines.
Tri-iso-Butyl Aluminum	See TRI-iso-BUTYL ALUMINUM plus Acids.

2-AMINOETHANOL $NH_2CH_2CH_2OH$

Acetic Acid	See ACETIC ACID plus 2-Aminoethanol.
Acetic Anhydride	See ACETIC ANHYDRIDE plus 2-Aminoethanol.
Acrolein	See ACROLEIN plus 2-Aminoethanol.
Acrylic Acid	See ACRYLIC ACID plus 2-Aminoethanol.
Acrylonitrile	See ACRYLONITRILE plus 2-Aminoethanol.
Chlorosulfonic Acid	Mixing 2-aminoethanol and chlorosulfonic acid in a closed container caused the temperature and pressure to increase. *Flynn and Rossow* (1970). See Note under complete reference.
Epichlorohydrin	Mixing 2-aminoethanol and epichlorohydrin in a closed container caused the temperature and pressure to increase. *Flynn and Rossow* (1970). See Note under complete reference.
Hydrochloric Acid	Mixing 2-aminoethanol and 36% hydrochloric acid in a closed container caused the temperature and pressure to increase. *Flynn and Rossow* (1970). See Note under complete reference.
Hydrofluoric Acid	Mixing 2-aminoethanol and 48.7% hydrofluoric acid in a closed container caused the temperature and pressure to increase. *Flynn and Rossow* (1970). See Note under complete reference.
Mesityl Oxide	See MESITYL OXIDE plus 2-Aminoethanol.
Nitric Acid	Mixing 2-aminoethanol and 70% nitric acid in a closed

	container caused the temperature and pressure to increase.
	Flynn and Rossow (1970). See Note under complete reference.
Oleum	Mixing 2-aminoethanol and oleum in a closed container caused the temperature and pressure to increase.
	Flynn and Rossow (1970). See Note under complete reference.
Propiolactone	Mixing 2-aminoethanol and propiolactone
(BETA-)	(BETA-) in a closed container caused the temperature and pressure to increase.
	Flynn and Rossow (1970). See Note under complete reference.
Sulfuric Acid	Mixing 2-aminoethanol and 96% sulfuric acid in a closed container caused the temperature and pressure to increase.
	Flynn and Rossow (1970). See Note under complete reference.
Vinyl Acetate	Mixing 2-aminoethanol and vinyl acetate in a closed container caused the temperature and pressure to increase.
	Flynn and Rossow (1970). See Note under complete reference.

AMINOGUANIDINE NITRATE $CH_6N_4 \bullet HNO_3$

(self-reactive)	Aminoguanidine nitrate in water solution exploded violently while being evaporated to dryness in vacuo on the steam bath. H. Koopman, *Chem. Weekblad* **53:** 97, 98 (1957).

2-AMINOTHIAZOLE $(SCHCHNC)NH_2$

(self-reactive)	2-Aminothiazole ignited in a tray dryer and was entirely consumed. Stability tests show that 2-aminothiazole will ignite spontaneously in 3 1/2 hours at 100¡C.
	MCA Case History **1587** (1969).

AMMONIA (ANHYDROUS) NH_3

Acetaldehyde	See ACETALDEHYDE plus Ammonia (Anhydrous).
Acrolein	See SODIUM HYDROXIDE plus Acrolein.
Boron	See BORON plus Ammonia.
Boron Triiodide	See BORON TRIIODIDE plus Ammonia.
Bromine	See BROMINE plus Ammonia.
Bromine Pentafluoride	See BROMINE PENTAFLUORIDE plus Acetic Acid.
Chloric Acid	See ANTIMONY plus Chloric Acid.
Chlorine	See CHLORINE plus Ammonia.
Chlorine Monoxide	See CHLORINE MONOXIDE plus Ammonia.
Chlorine Trifluoride	See CHLORINE TRIFLUORIDE plus Ammonia.
Chlorites	See CHLORITES plus Ammonia.
Chlorosilane	See CHLOROSILANE plus Ammonia.
Chromic Anhydride	See CHROMIC ANHYDRIDE plus Ammonia.
Chromium Trioxide	See CHROMIC ANHYDRIDE plus Ammonia.
Chromyl Chloride	See CHROMYL CHLORIDE plus Ammonia.
Ethylene Dichloride	Liquid ammonia and ethylene dichloride can cause an explosion when mixed.
	Mukerjee (1970).
Ethylene Oxide	During manufacture of ethanolamine, an excess of ammonia during a period of high pressure resulted in an ammonia-ethylene oxide explosion.
	MCA Case History **792** (1962).
Fluorine	See FLUORINE plus Ammonia.
Gold	See GOLD plus Ammonia.
Hexachloromelamine	See HEXACHLOROMELAMINE plus Organic Contaminants.

Hydrazine and Alkali Metals	See HYDRAZINE plus Alkali Metals and Ammonia.
Hydrogen Bromide	See HYDROGEN BROMIDE plus Ammonia.
Hypochlorous Acid	See HYPOCHLOROUS ACID plus Ammonia.
Iodine	See IODINE plus Ammonia.
Magnesium Perchlorate	See MAGNESIUM PERCHLORATE plus Ammonia.
Mercury	See MERCURY plus Ammonia. See also GOLD plus Ammonia.
Nitric Acid	See NITRIC ACID plus Ammonia.
Nitrogen Peroxide	See NITRIC OXIDE plus Ammonia.
Nitrogen Tetroxide	See NITROGEN TETROXIDE plus Ammonia.
Nitrogen Trichloride	See NITROGEN TRICHLORIDE plus Ammonia.
Nitrogen Trifluoride	See HYDROGEN plus Nitrogen Trifluoride.
Nitryl Chloride	See NITRYL CHLORIDE plus Ammonia.
Oxygen Difluoride	See OXYGEN DIFLUORIDE plus Ammonia.
Phosphorus Pentoxide	See PHOSPHORUS PENTOXIDE plus Ammonia.
Phosphorus Trioxide	See PHOSPHORUS TRIOXIDE plus Ammonia.
Picric Acid	See PICRIC ACID plus Ammonia.
Potassium and Arsine	See POTASSIUM plus Arsine and Ammonia.
Potassium and Phosphine	See POTASSIUM plus Phosphine and Ammonia.
Potassium and Sodium Nitrite	See POTASSIUM plus Sodium Nitrite and Ammonia.
Potassium Chlorate	See POTASSIUM CHLORATE plus Ammonia.
Potassium Ferricyanide	See POTASSIUM FERRICYANIDE plus Ammonia.
Potassium Mercuricyanide	See POTASSIUM MERCURICYANIDE plus Ammonia.
Silver	See GOLD plus Ammonia.

Silver Chloride	See SILVER CHLORIDE plus Ammonia.
Sodium and Carbon Monoxide	See SODIUM plus Carbon Monoxide and Ammonia.
Stibine	See STIBINE plus Ammonia.
Sulfur	See SULFUR plus Ammonia.
Sulfur Dichloride	See SULFUR DICHLORIDE plus Ammonia.
Tellurium Hydropentachloride	See TELLURIUM HYDROPENTACHLORIDE plus Ammonia.
Trichloromelamine	See HEXACHLOROMELAMINE plus Organic Contaminants.

AMMONIUM ACETATE CH_3COONH_4

Sodium Hypochlorite	See SODIUM HYPOCHLORITE plus Ammonium Acetate.

AMMONIUM AZIDE NH_4N_5

(self-reactive)	Ammonium azide decomposes at 160¡C.
	Mellor **8, Supp. 2:** 43 (1967).

AMMONIUM BROMIDE NH_4Br

Bromine Trifluoride	See BROMINE TRIFLUORIDE plus Ammonium Bromide.
Iodine Heptafluoride	See IODINE HEPTAFLUORIDE plus Ammonium Bromide.
Potassium	See POTASSIUM plus Ammonium Bromide.

AMMONIUM CARBONATE $(NH_4)_2CO_2$

Sodium Hypochlorite	See SODIUM HYPOCHLORITE plus Ammonium Acetate.

AMMONIUM CHLORATE NH_4ClO_3

(self-reactive)	The solid is an explosive compound. Solutions may decompose violently if much solid phase is present. *Mellor* **2, Supp. 1:** 591 (1956).

AMMONIUM CHLORIDE NH_4Cl

Ammonium Nitrate	See AMMONIUM NITRATE plus Ammonium Chloride.
Bromine Trifluoride	See BROMINE TRIFLUORIDE plus Ammonium Bromide.
Iodine Heptafluoride	See IODINE HEPTAFLUORIDE plus Ammonium Bromide.
Potassium Chlorate	See POTASSIUM CHLORATE plus Ammonium Chloride.

AMMONIUM DICHROMATE $(NH_4)_2Cr_2O_7$

(self-reactive)	Ammonium dichromate decomposes vigorously with luminescence around 200¡C. It is feebly explosive if confined. *Mellor* **11:** 324 (1946-1947).

AMMONIUM HEXANITROCOBALTATE $(NH_4)_3CO(NO_2)_6$

(self-reactive)	Ammonium hexanitrocobaltate explodes at 230¡C and is impact sensitive. W. R. Tomlinson, Jr., and L. F. Audrieth, *J. Chem. Ed.* **27:** 606-9 (1950).

AMMONIUM HYDROXIDE NH_4OH

Acrolein	See ACROLEIN plus Ammonium Hydroxide.
Acrylic Acid	See ACRYLIC ACID plus Ammonium Hydroxide.
Chlorosulfonic Acid	See CHLOROSULFONIC ACID plus Ammonium

	Hydroxide.
Dimethyl Sulfate	Pure dimethyl sulfate and concentrated aqueous ammonia react extremely violently with one another.
	Berichte **13:** 1700 (1880).
Fluorine	See FLUORINE plus Ammonium Hydroxide.
Gold and Aqua Regia	See GOLD plus Ammonium Hydroxide and Aqua Regia.
Hydrochloric Acid	See HYDROCHLORIC ACID plus Ammonium Hydroxide.
Hydrofluoric Acid	See HYDROFLUORIC ACID plus Ammonium Hydroxide.
Iodine	See IODINE plus Ammonium Hydroxide.
Nitric Acid	See NITRIC ACID plus Ammonium Hydroxide.
Oleum	See OLEUM plus Ammonium Hydroxide.
Propiolactone (BETA)	See PROPIOLACTONE (BETA) plus Ammonium Hydroxide.
Propylene Oxide	See PROPYLENE OXIDE plus Ammonium Hydroxide.
Silver Nitrate	See SILVER NITRATE plus Acetylene and Ammonium Hydroxide. See SILVER NITRATE plus Ammonium Hydroxide.
Silver Oxide	See SILVER OXIDE plus Ammonium Hydroxide.
Silver Oxide and	See SILVER OXIDE plus Aqueous Ammonia
Ethyl Alcohol	and Ethyl Alcohol.
Silver Permanganate	See SILVER PERMANGANATE plus Ammonium Hydroxide.
Sulfuric Acid	See SULFURIC ACID plus Ammonium Hydroxide.

AMMONIUM HYPOPHOSPHITE $NH_2PH_2O_2$

(self-reactive)	Ammonium hypophosphite liberates spontaneously flammable phosphine at about 240¡C.
	Mellor **8:** 880 (1946-1947).

AMMONIUM IODIDE NH_4I

Bromine Trifluoride	See BROMINE TRIFLUORIDE plus Ammonium Bromide.
Iodine Heptafluoride	See IODINE HEPTAFLUORIDE plus Ammonium Bromide.
Potassium	See POTASSIUM plus Ammonium Bromide.

AMMONIUM NITRATE NH_4NO_3

Acetic Acid	A mixture of ammonium nitrate and acetic acid ignites when warmed, especially if concentrated.
	Von Schwartz, p. 322 (1918).
Aluminum	See ALUMINUM plus Ammonium Nitrate.
Ammonium Chloride	The decomposition of ammonium nitrate in the presence of ammonium chloride (0.1%) becomes violent around 175¡C. The gases liberated contain chlorine.
	Pascal **10:** 216 (1931-1934).
Antimony	See AMMONIUM NITRATE plus Metals (powdered).
Bismuth	See AMMONIUM NITRATE plus Metals (powdered).
Cadmium	See AMMONIUM NITRATE plus Metals (powdered).
Carbon	See CARBON plus Ammonium Nitrate.
Chlorides	See AMMONIUM NITRATE plus Ammonium Chloride.
Chromium	See AMMONIUM NITRATE plus Metals (powdered).
Cobalt	See AMMONIUM NITRATE plus Metals (powdered).
Contaminant	During the flame-cutting of a pipeline plugged with impure ammonium nitrate, the pipe contents exploded violently.
	MCA Case History **873** (1963).
Copper	See AMMONIUM NITRATE plus Metals (powdered).
	See COPPER plus Ammonium Nitrate.
Lead	See AMMONIUM NITRATE plus Metals (powdered).

Magnesium	See AMMONIUM NITRATE plus Metals (powdered).
Magnesium, Copper Sulfate (anhydrous), Potassium Chlorate and Water	See MAGNESIUM plus Copper Sulfate (anhydrous), Ammonium Nitrate, Potassium Chlorate and Water.
Metals (powdered)	Fused ammonium nitrate with powdered metals is often a violent and sometimes an explosive reaction. Zinc, cadmium, copper, magnesium, lead, cobalt, nickel, bismuth, chromium, and antimony are the metals that reacted in this way.
	Mellor **Supp. I, Part I, 8:** 545 (1964).
	See also SULFUR plus Ammonium Nitrate.
	See also ALUMINUM plus Ammonium Nitrate.
Nickel	See AMMONIUM NITRATE plus Metals (powdered).
Organic Matter	Ammonium nitrate forms explosive mixtures with organic matter.
	Hazardous Chemicals Data (1966); *Lab. Govt. Chemist.*
Phosphorus	See PHOSPHORUS plus Ammonium Nitrate.
Potassium and Ammonium Sulfate	See POTASSIUM plus Ammonium Sulfate and Ammonium Nitrate.
Sodium	See SODIUM plus Ammonium Nitrate.
Sodium Hypochlorite	See SODIUM HYPOCHLORITE plus Ammonium Acetate.
Sodium Perchlorate	See SODIUM PERCHLORATE plus Ammonium Nitrate.
Sodium-Potassium Alloy and Ammonium Sulfate	See POTASSIUM plus Ammonium Sulfate and Ammonium Nitrate.
Sulfur	See SULFUR plus Ammonium Nitrate.
Zinc	See ZINC plus Ammonium Nitrate.

	See also AMMONIUM NITRATE plus Metals (powdered).

AMMONIUM NITRIDOOSMATE NH_4OsNO_3

(self-reactive)	Ammonium osmiamate decomposes explosively at 150¡C.
	Mellor **15:** 727 (1946-1947).

AMMONIUM OXALATE $(NH_4OOC-)_2$

Sodium Hypochlorite	See SODIUM HYPOCHLORITE plus Ammonium Acetate.

AMMONIUM PERCHLORATE NH_4ClO_4

(self-reactive)	Ammonium perchlorate decomposes at 130¡ C and explodes at 380¡ C.
	Mellor **2, Supp. 1:** 608 (1956).
Carbon	See CARBON plus Ammonium Perchlorate.
Dicyclopentadienyliron	Explosions have occurred in propellant formulations using dicyclopentadienyliron (ferrocene), as a burning rate catalyst. Although the definite cause has not been established, the most probable cause is the heat of friction between the mixer sidewall and the spatula while the latter was scraping through a mixture of ammonium perchlorate and sublimed recrystallized ferrocenes.
	ASESB Expl. Report **211** (1966).
Ferrocene	See AMMONIUM PERCHLORATE plus Dicyclopentadienyliron.
Metals	See SULFUR plus Ammonium Perchlorate.
Organic Matter	See SULFUR plus Ammonium Perchlorate.
Sulfur	See SULFUR plus Ammonium Perchlorate.

AMMONIUM PERIODATE NH_4IO_4

(self-reactive)	See PERIODATES (self-reactive).

AMMONIUM PERMANGANATE NH_4MnO_4

(self-reactive)	Dry ammonium permanganate is explosive at 60¡ C and is likely to explode when rubbed. *Lab. Govt. Chemist* (1965).

AMMONIUM PERSULFATE $(NH_4)_2S_2O_8$

Aluminum	See ALUMINUM plus Ammonium Persulfate.
Sodium Peroxide	A mixture of ammonium persulfate and sodium peroxide will explode if subjected to crushing (in a mortar), heating, or if a stream of carbon dioxide is passed over it. *Mellor* **10:** 464 (1946-1947).

AMMONIUM PHOSPHATE $NH_4H_2PO_4$

Sodium Hypochlorite	See SODIUM HYPOCHLORITE plus Ammonium Acetate.

AMMONIUM PICRATE $C_6H_2(NO_3)_3ONH_4$

(self-reactive)	Small traces of metallic picrates may lower appreciably the temperature at which such mixtures will explode. *Military Explosives*, p. 96.
Metals	Explodes when heated to a temperature of about 300¡ C. *Military Explosives*, p. 96.

AMMONIUM SALTS

(See also specific ammonium salt)

Potassium Chlorate	See POTASSIUM CHLORATE plus Ammonium Salts.
Sodium Nitrite	See SODIUM NITRITE plus Ammonium Salts.

AMMONIUM SULFATE $(NH_4)_2SO_4$

Potassium and Ammonium Nitrate	See POTASSIUM plus Ammonium Sulfate and Ammonium Nitrate.
Potassium Chlorate	See POTASSIUM CHLORATE plus Ammonium Sulfate.
Potassium Nitrite	See POTASSIUM NITRITE plus Ammonium Sulfate.
Sodium-Potassium Alloy and Ammonium Nitrate	See POTASSIUM plus Ammonium Sulfate and Ammonium Nitrate.

AMMONIUM TETRACHLOROCUPRATE $(NH_4)_2CuCl_4$

Potassium	See POTASSIUM plus Aluminum Bromide.
Sodium	See SODIUM plus Aluminum Bromide.

AMMONIUM TETRACHROMATE $(NH_4)_2Cr_4O_{13}$

(self-reactive)	Ammonium tetrachromate decomposes suddenly at 175¡ C.
	Mellor **11:** 352 (1946-1947).

AMMONIUM TETRAPEROXYCHROMATE $(NH_4)_3$ Cr $(OO)_4$

(self-reactive)	Ammonium triperchromate explodes from percussion or if heated just to 50¡ C.
	Mellor **11:** 356 (1946-1947).
Sulfuric Acid	Contact between these compounds results in an explosion.
	Mellor **11:** 356 (1946-1947).

AMMONIUM THIOCYANATE NH_4SCN

Lead Nitrate	An explosion of guanidine nitrate demolished an autoclave built to withstand 50 atmospheres, in which it was being

	made from ammonium thiocyanate and lead nitrate. C. Schopf and H. Klapproth.
	Angew. Chem. **49:** 23 (1936).

AMMONIUM THIOSULFATE $NH_4S_2O_3$

Sodium Chlorate	See SODIUM CHLORATE plus Ammonium Thiosulfate.

AMMONIUM TRICHROMATE $(NH_4)_2Cr_3O_{10}$

(self-reactive)	Ammonium trichromate detonates at about 190¡ C.
	Mellor **11:** 350 (1946-1947).

AMYL ALCOHOL $C_5H_{11}OH$

Hydrogen Trisulfide	See HYDROGEN TRISULFIDE plus Amyl Alcohol.

ANILINE $C_6H_5NH_2$

Acetic Anhydride	Mixing aniline and acetic anhydride in a closed container caused the temperature and pressure to increase.
	Flynn and Rossow (1970). See Note under complete reference.
Chlorosulfonic Acid	Mixing aniline and chlorosulfonic acid in a closed container caused the temperature and pressure to increase.
	Flynn and Rossow (1970). See Note under complete reference.
Hexachloromelamine	See HEXACHLOROMELAMINE plus Organic Contaminants.
Nitric Acid	See NITRIC ACID plus Aniline.
Nitric Acid, Nitrogen Tetroxide, and Sulfuric Acid	See UNSYMMETRICAL DIMETHYLHYDRAZINE plus Nitric Acid, Nitrogen Tetroxide, and Sulfuric Acid.

Nitrobenzene and Glycerine	In the reaction of these three ingredients to form quinoline, with ferrous sulfate as catalyst, there was too much sulfuric acid and too little water present. The resultant excessive temperature initiated a runaway reaction. The rupture disc and the manhole cover of the vessel blew out; the contents erupted from the vessel.
	MCA Case History **1008** (1964).
Oleum	Mixing aniline and oleum in a closed container caused the temperature and pressure to increase.
	Flynn and Rossow (1970). See Note under complete reference.
Ozone	See OZONE plus Aniline.
Perchloric Acid and Formaldehyde	See PERCHLORIC ACID plus Aniline and Formaldehyde.
Perchromates	See PERCHROMATES plus Aniline.
Performic Acid	See PERFORMIC ACID plus Aniline.
Potassium Peroxide	See SODIUM PEROXIDE plus Aniline.
Propiolactone (BETA-)	Mixing aniline and propiolactone (BETA-) in a closed container caused the temperature and pressure to increase.
	Flynn and Rossow (1970). See Note under complete reference.
Silver Perchlorate	See SILVER PERCHLORATE plus Toluene.
	See SILVER PERCHLORATE plus Acetic Acid.
Sodium Peroxide	See SODIUM PEROXIDE plus Aniline.
Sulfuric Acid	Mixing aniline and 96% sulfuric acid in a closed container caused the temperature and pressure to increase.
	Flynn and Rossow (1970). See Note under complete reference.
Trichloromelamine	See HEXACHLOROMELAMINE plus Organic Contaminants.

ANISOYL CHLORIDE $CH_3OC_6H_4COCl$

(self-reactive)	A 5-pound bottle containing anisoyl chloride on the laboratory shelf exploded during the night. During cleanup, workers sustained painful eye burns. After several weeks storage in a dessicator at room temperature, a 200-gram bottle of commercial anisoyl chloride exploded with copious emission of hydrogen chloride. *Chem. Eng. News* **38** (34): 40 (1960); **38** (43): 5 (1960).

ANTHRACENE $C_6H_4(CH)_2C_6H_4$

Calcium Hypochlorite	See CALCIUM HYPOCHLORITE plus Anthracene.
Chromic Acid	See CHROMIC ANHYDRIDE plus Anthracene.

ANTIMONY Sb

Ammonium Nitrate	See AMMONIUM NITRATE plus Metals (powdered).
Bromine	Antimony is spontaneously flammable in fluorine, chlorine, or bromine. With iodine, the reaction produces heat, which can cause flame or even an explosion if the quantities are great enough. *Mellor* **9:** 379 (1946-1947).
Bromine Trifluoride	Even at 10¡ C., bromine trifluoride reacts with antimony incandescently. Bromine trifluoride reacts similarly with arsenic, boron, bromine, iodine, phosphorus, and sulfur. *Mellor* **2:** 113 (1946-1947).
Bromoazide	Bromoazide explodes on contact with antimony, arsenic, phosphorus, silver foil or sodium. It is very sensitive to shock and the resulting explosions appear to be spontaneous. *Mellor* **8:** 336 (1946-1947).
Chloric Acid	Explosions of chloric acid have been due to the formation of explosive compounds with antimony, bismuth, ammonia, and organic matter. *Chem. Abst.* **46:** 2805c (1952).

Chlorine	Antimony burns spontaneously in gaseous chlorine. With liquid chlorine, antimony ignites at 33¡ C.
	Mellor **2:** 92-95; **9:** 379, 626 (1946-1947).
Chlorine Monoxide	See POTASSIUM plus Chlorine Monoxide.
Chlorine Trifluoride	Chlorine trifluoride reacts vigorously with antimony, arsenic, osmium, phosphorus, potassium, rhodium, selenium, silicon, sulfur, tellurium, or tungsten, producing flame.
	Mellor **2, Supp. 1:** 156 (1956).
Fluorine	See ANTIMONY plus Bromine.
Iodine	See ANTIMONY plus Bromine.
Nitric Acid	The reaction of finely divided antimony and nitric acid can be violent.
	Pascal **10:** 504 (1931-1934).
Potassium Nitrate	Powdered antimony mixed with an alkali nitrate explodes when heated.
	Mellor **9:** 282 (1946-1947).
Potassium Permanganate	When antimony or arsenic and solid potassium permanganate are ground together, the metals ignite.
	Mellor **12:** 322 (1946-1947).
Potassium Peroxide	See POTASSIUM plus Potassium Peroxide.
Sodium Nitrate	See ANTIMONY plus Potassium Nitrate.
Sodium Peroxide	Sodium peroxide oxidizes antimony, arsenic, copper, potassium, tin and zinc with incandescence.
	Mellor **2:** 490-93 (1946-1947).

ANTIMONY COMPOUNDS (Trivalent)

Perchloric Acid	Trivalent antimony compounds tend to form explosive mixtures with perchloric acid when hot.
	Analyst **84:** 215 (April 1959). *Chem. Eng. News* **41** (31): 47 (1963).

ANTIMONYL CHLORIDE SbOCl

Bromine Trifluoride	See BROMINE TRIFLUORIDE plus Antimony Trioxide.

ANTIMONYL PERCHLORATE $SbOClO_4$

(self-reactive)	This chemical decrepitates when heated above 60¡ C.
	Mellor **2, Supp. 1:** 613 (1956).

ANTIMONY PENTAFLUORIDE SbF_5

Phosphorus	See PHOSPHORUS plus Antimony Pentafluoride.

ANTIMONY SULFIDE Sb_2S_3;Sb_2S_5

(See also ANTIMONY TRISULFIDE)

Air	When the crystalline form of antimony trisulfide is heated in air, it burns with a blue flame.
	Mellor **9:** 522 (1946-1947).
Cadmium Chlorate	See CHLORATES plus Antimony Sulfide.
Chlorates	See CHLORATES plus Antimony Sulfide.
Chloric Acid	Antimony sulfide and concentrated solutions of chloric acid react with incandescence.
	Mellor **Supp. II, Part I:** 584 (1956).
Chlorine Monoxide	See CHLORINE MONOXIDE plus Calcium Phosphide.
Magnesium Chlorate	See CHLORATES plus Antimony Sulfide.
Thallic Oxide	See THALLIC OXIDE plus Antimony Sulfide.
Zinc Chlorate	See CHLORATES plus Antimony Sulfide.

ANTIMONY TRIBROMIDE $SbBr_3$

Potassium	See POTASSIUM plus Aluminum Bromide.
Sodium	See SODIUM plus Aluminum Bromide.

ANTIMONY TRICHLORIDE $SbCl_3$

Aluminum	See ALUMINUM plus Phosphorus Trichloride.
Potassium	See POTASSIUM plus Aluminum Bromide.
Sodium	See SODIUM plus Aluminum Bromide.

ANTIMONY TRIETHYL

(See TRIETHYL ANTIMONY)

ANTIMONY TRIIODIDE SbI_3

Potassium	See POTASSIUM plus Aluminum Bromide.
Sodium	See SODIUM plus Aluminum Bromide.

ANTIMONY TRIMETHYL

(See TRIMETHYL ANTIMONY)

ANTIMONY TRIOXIDE Sb_2O_3

Air	When powdered antimony trioxide is heated in air, it ignites and burns. *Mellor* **9:** 425 (1946-1947).
Bromine Trifluoride	See BROMINE TRIFLUORIDE plus Antimony Trioxide.

ANTIMONY TRIPROPYL $(C_3H_7)_3Sb$

(See TRIPROPYL ANTIMONY)

ANTIMONY TRISULFIDE Sb_2S_3

Chlorine Monoxide	See CHLORINE MONOXIDE plus Calcium Phosphide.
Fluorine	See FLUORINE plus Antimony Trisulfide.
Hydrogen Peroxide	Hydrogen peroxide reacts vigorously with antimony trisulfide, arsenic trisulfide, cupric sulfide, lead sulfide, molybdenum disulfide, and ferrous sulfide.
	Mellor **1:** 937 (1946-1947).
Potassium Chlorate	See POTASSIUM CHLORATE plus Antimony Trisulfide.
Potassium Nitrate	See POTASSIUM NITRATE plus Antimony Trisulfide.
Silver Oxide	See SILVER OXIDE plus Antimony Trisulfide.

ANTIMONY TRIVINYL $(CH{=}CH)_3Sb$

(See TRIVINYL ANTIMONY)

ARSENIC As

Barium Bromate	See ARSENIC plus Bromates.
Barium Chlorate	See ARSENIC plus Bromates.
Barium Iodate	See ARSENIC plus Bromates.
Bromates	A combination of finely divided arsenic with finely divided bromates (also chlorates and iodates) of barium, calcium, magnesium, potassium, sodium, or zinc can be exploded by heat, percussion, and sometimes, by light friction.
	Mellor **2:** 310 (1946-1947).
Bromine Pentafluoride	Bromine pentafluoride reacts readily in the cold with arsenic, charcoal, selenium, sulfur, iodine, and alkaline chlorides, bromides, and iodides; ignition usually occurs. A few drops of the liquid falling in water produces an explosion.
	Sidgwick, p. 1158 (1950).
Bromine Trifluoride	See ANTIMONY plus Bromine Trifluoride.

Bromoazide	See ANTIMONY plus Bromoazide.
Calcium Bromate	See ARSENIC plus Bromates.
Calcium Chlorate	See ARSENIC plus Bromates.
Calcium Iodate	See ARSENIC plus Bromates.
Cesium Acetylene	The carbide becomes incandescent when
Carbide	warmed in contact with arsenic.
	Mellor **5:** 848-50 (1946-1947).
Chlorates	See ARSENIC plus Bromates.
Chlorine	Arsenic burns spontaneously in gaseous chlorine. With liquid chlorine, arsenic ignites at 33¡ C.
	Mellor **2:** 92, 95; **9:** 626 (1946-1947).
Chlorine Monoxide	See POTASSIUM plus Chlorine Monoxide.
Chlorine Trifluoride	See ANTIMONY plus Chlorine Trifluoride.
Chromium Trioxide	Arsenic reacts with chromium trioxide with incandescence.
	Mellor **11:** 232 (1946-1947).
Fluorine	See FLUORINE plus Arsenic.
Hypochlorous Acid	Arsenic ignites with hypochlorous acid.
	Mellor **2:** 254 (1946-1947).
Iodates	See ARSENIC plus Bromates.
Iodine Pentafluoride	Iodine pentafluoride reacts spontaneously with sulfur, red phosphorus, silicon, bismuth, tungsten, and arsenic, usually with incandescence. Organic compounds react violently, usually carbonizing and often igniting.
	Durrant, p. 515 (1953). *Sidgwick,* p. 1159 (1950).
Lithium	See LITHIUM plus Arsenic.
Magnesium Bromate	See ARSENIC plus Bromates.
Magnesium Chlorate	See ARSENIC plus Bromates.
Magnesium Iodate	See ARSENIC plus Bromates.
Nitrogen Tribromide	Nitrogen tribromide explodes violently in contact with

	arsenic or phosphorus.
	Ann. Chim. et Phys. (2) **42:** 200.
Nitrogen Trichloride	Nitrogen trichloride explodes in contact with powdered arsenic. Also see NITROGEN TRICHLORIDE plus Ammonia.
	Mellor **8:** 602 (1946-1947).
Potassium Bromate	See ARSENIC plus Bromates.
Potassium Chlorate	See ARSENIC plus Bromates.
Potassium Iodate	See ARSENIC plus Bromates.
Potassium Nitrate	A mixture of arsenic and potassium nitrate explodes when ignited.
	Mellor **9:** 35 (1946-1947).
Potassium Permanganate	See ANTIMONY plus Potassium Permanganate.
Potassium Peroxide	See POTASSIUM plus Potassium Peroxide.
Rubidium Acetylene	Rubidium acetylene carbide becomes incandescent
Carbide	when warmed in contact with arsenic.
	Mellor **5:** 849 (1946-1947).
Rubidium Carbide	A mixture of rubidium carbide and arsenic ignites when heated.
	Mellor **5:** 848 (1946-1947).
Silver Nitrate	A mixture of sublimed arsenic ground with 10 times its weight of silver nitrate ignites immediately when shaken out on paper.
	Mellor **3:** 470 (1946-1947).
Sodium Bromate	See ARSENIC plus Bromates.
Sodium Chlorate	See ARSENIC plus Bromates.
Sodium Iodate	See ARSENIC plus Bromates.
Sodium Peroxide	Sodium peroxide oxidizes arsenic with incandescence.
	Mellor **2:** 490-93 (1946-1947).

Zinc Bromate	See ARSENIC plus Bromates.
Zinc Chlorate	See ARSENIC plus Bromates.
Zinc Iodate	See ARSENIC plus Bromates.

ARSENIC DISULFIDE As_2S_2

Air	Arsenic disulfide burns with a blue flame when heated in air.
	Mellor **9:** 270 (1946-1947).
Chlorine	See CHLORINE plus Arsenic Disulfide.
Potassium Nitrate	See POTASSIUM NITRATE plus Arsenic Disulfide.

ARSENIC OXIDE As_2O_3; As_2O_5

Rubidium Carbide	See RUBIDIUM CARBIDE plus Arsenic Oxide.

ARSENIC SULFIDE As_2S_2; As_2S_3; As_2S_5

Cadmium Chlorate	See CHLORATES plus Arsenic Sulfide.
Chlorates	See CHLORATES plus Arsenic Sulfide.
Chloric Acid	Arsenic sulfide and concentrated solutions of chloric acid react with incandescence.
	Mellor **Supp. II, Part I:** 584 (1956).
Magnesium Chlorate	See CHLORATES plus Arsenic Sulfide.
Zinc Chlorate	See CHLORATES plus Arsenic Sulfide.

ARSENIC TRICHLORIDE $AsCl_3$

Aluminum	See ALUMINUM plus Phosphorus Trichloride.
Aluminum Fluoride	See SODIUM plus Aluminum Bromide.
Ammonium	See SODIUM plus Aluminum Bromide.

Chlorocuprate

Antimony Tribromide	See SODIUM plus Aluminum Bromide.
Antimony Trichloride	See SODIUM plus Aluminum Bromide.
Antimony Triiodide	See SODIUM plus Aluminum Bromide.
Arsenic Trichloride	See SODIUM plus Aluminum Bromide.
Arsenic Triiodide	See SODIUM plus Aluminum Bromide.
Potassium	See POTASSIUM plus Aluminum Bromide.
Sodium	See SODIUM plus Aluminum Bromide.

ARSENIC TRIETHYL

(See TRIETHYL ARSINE)

ARSENIC TRIFLUORIDE AsF_3

Phosphorus Trioxide	This reaction is very violent. *Mellor* **8, Supp. 3:** 382 (1971).

ARSENIC TRIMETHYL

(See TRIMETHYL ARSENIC)

ARSENIC TRIIODIDE AsI_3

Potassium	See POTASSIUM plus Aluminum Bromide.
Sodium	See SODIUM plus Aluminum Bromide.

ARSENIC TRIOXIDE As_2O_3

Chlorine Trifluoride	See CHLORINE TRIFLUORIDE plus Arsenic Trioxide.
Fluorine	See FLUORINE plus Arsenic Trioxide.
Hydrogen Fluoride	See HYDROGEN FLUORIDE plus Arsenic Trioxide.

Oxygen Difluoride	See OXYGEN DIFLUORIDE plus Aluminum Chloride.
Sodium Chlorate	See SODIUM CHLORATE plus Arsenic Trioxide.

ARSENIC TRISILYL $(SiH_3)_3As$

(See TRISILYLARSINE)

ARSENIC TRISULFIDE As_2S_3

Hydrogen Peroxide	See ANTIMONY TRISULFIDE plus Hydrogen Peroxide.
Sulfur and Potassium Nitrate	See SULFUR plus Potassium Nitrate and Arsenic Trisulfide.

ARSINE AsH_3

Chlorine	See CHLORINE plus Arsine.
Nitric Acid	See NITRIC ACID plus Arsine.
Potassium and Ammonia	See POTASSIUM plus Arsine and Ammonia.

ARYL HALIDES

(See DIMETHYL SULFOXIDE plus Acyl Halides)

ASPHALT

Fluorine	See FLUORINE plus Common Materials and Oxygen.

AZIDES

(See also specific azide)

Carbon Disulfide	Carbon disulfide plus any of the azides produces violently explosive, extremely sensitive salts.

Mellor **8:** 338 (1946-1947).

AZIDES (ORGANIC)

Acids

Trace amounts of strong acid, certain metal salts, or conceivably other materials may catalyze explosive reactions with organic azides.

Chem. Eng. News **42** (31): 6 (1964).

Metal Salts

See AZIDES (ORGANIC) plus Acids.

AZIDOALKANES NNNR

(self-reactive)

See ALKYL AZIDES (self-reactive).

4-AZIDO-N,N-DIETHYLANILINE $NNNC_6H_4N(C_2H_5)_2$

(self-reactive)

An attempt to distill this compound resulted in violent decomposition.

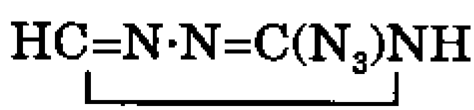
NSC Newsletter, R & D Sec. (July 1973).

AZIDOFLUORINE N_3F

(self-reactive)

See FLUORINE AZIDE (self-reactive).

3-AZIDO-S-TRIAZOLE



(self-reactive)

Samples of this compound detonated during melting point determinations, breaking combustion tubes.

DeNault, Marx and Takimoto, *J. Chem. Eng. Data* **13:** 514-516 (1968).

AZINE FLUORIDE

(See FLUORINE AZIDE)

a,a'-AZODIISOBUTYRONITRILE $[NCC(CH_3)_2N=]_2$

(self-reactive)	An explosion occurred when a solution of a,a'-azodiisobutyronitrile in acetone was concentrated in a glass-lined, steam-jacketed vessel.
	P. J. Carlisle, *Chem. Eng. News* **27:** 150 (1949).

BAKELITE

Fluorine	See FLUORINE plus Solid Nonmetals.

BARIUM Ba

Acids	Barium reacts violently with acids.
	Lab. Govt. Chemist (1965).
Carbon Tetrachloride	A violent reaction occurred when small chunks of barium were cleaned by submerging in chemically pure carbon tetrachloride. See also BARIUM plus Trichlorotrifluoroethane.
	Serious Acc. Series **23** (1952) and **Supp.** (Sept. 30, 1952).
Monofluorotrichloromethane	See BARIUM plus Trichlorotrifluoroethane.
Tetrachloroethylene	See BARIUM plus Trichlorotrifluoroethane.
Trichloroethylene	See BARIUM plus Trichlorotrifluoroethane.
Trichlorotrifluoroethane	It has been determined experimentally that mixtures of finely divided barium metal and a number of halogenated hydrocarbons possess an explosive capability. Specifically, impact sensitivity tests have shown that granular barium in contact with monofluorotrichloromethane, trichlorotrifluoroethane, carbon tetrachloride, trichloroethylene, or tetrachloroethylene can detonate.

	ASESB Pot. Incid. **39** (1968). *Aero. and Astro.*
	6 (3):82 (1968). *Chem. Eng. News* **46** (9):38 (1968).
Water	Barium rapidly decomposes water. The heat of reaction is sufficient that the evolved hydrogen may ignite.
	Lab. Govt. Chemist (1965).

BARIUM ALLOYS

Acids	Alloys containing a substantial proportion of barium react violently with acids.
	Lab. Govt. Chemist (1965).
Water	Alloys containing a substantial proportion of barium rapidly decompose water. The heat of reaction is sufficient that the evolved hydrogen may ignite.
	Lab. Govt. Chemist (1965).

BARIUM AZIDE $Ba(N_3)_2$

(self-reactive)	Barium azide decomposes at 275¡C. It is explosively unstable.
	Mellor **8, Supp. 2:** 43 (1967).
Air	Barium azide is spontaneously flammable in air.
	Ripley (1966).

BARIUM BROMATE $Ba(BrO_3)_2$

Aluminum	See ALUMINUM plus Bromates.
Arsenic	See ARSENIC plus Bromates.
Carbon	See CARBON plus Bromates.
Copper	See COPPER plus Bromates.
Metal Sulfides	See METAL SULFIDES plus Bromates.
Organic Matter	See BROMATES plus Organic Matter.

Phosphorus	See PHOSPHORUS plus Bromates.
Sulfur	See SULFUR plus Bromates.

BARIUM CARBIDE BaC_2

Selenium	See SELENIUM plus Barium Carbide.
Sulfur	See SULFUR plus Barium Carbide.
Water	Barium carbide will flame in contact with water.
	Ellern, p. 45 (1968).

BARIUM CHLORATE $Ba(ClO_3)_2$

Aluminum	See ALUMINUM plus Bromates.
Arsenic	See ARSENIC plus Bromates.
Carbon	See CARBON plus Bromates.
Charcoal	See CHLORATES plus Organic Matter.
Copper	See COPPER plus Bromates.
Manganese Dioxide	See CHLORATES plus Manganese Dioxide.
Metal Sulfides	See METAL SULFIDES plus Bromates.
Nitrogen Sulfide	See NITROGEN SULFIDE plus Barium Chlorate.
Organic Matter	See BROMATES plus Organic Matter.
	See CHLORATES plus Organic Matter.
Phosphorus	See PHOSPHORUS plus Bromates.
Sulfur	See SULFUR plus Bromates. See SULFUR plus Chlorates.
	See SULFUR plus Barium Chlorate.

BARIUM CHLORIDE $BaCl_2$

Bromine Trifluoride	See BROMINE TRIFLUORIDE plus Barium Chloride.
2-Furan Percarboxylic	See 2-FURAN PERCARBOXYLIC ACID

Acid	(self-reactive).

BARIUM HYDRIDE BaH_2

Air	See BARIUM HYDRIDE plus Water.
Water	Barium hydride reacts vigorously with water. If finely powdered, it ignites spontaneously in moist air or dry air.
	Hurd, p. 48 (1952).

BARIUM HYPOPHOSPHITE $Ba(H_2PO_2)_2 \cdot H_2O$

Potassium Chlorate	See POTASSIUM CHLORATE plus Barium Hypophosphite.

BARIUM IODATE $Ba(IO_3)_2$

Aluminum	See ALUMINUM plus Bromates.
Arsenic	See ARSENIC plus Bromates.
Carbon	See CARBON plus Bromates.
Copper	See COPPER plus Bromates.
Metal Sulfides	See METAL SULFIDES plus Bromates.
Organic Matter	See BROMATES plus Organic Matter.
Phosphorus	See PHOSPHORUS plus Bromates.
Sulfur	See SULFUR plus Bromates.

BARIUM NITRATE $Ba(NO_3)_2$

Barium Dioxide, Magnesium, and Zinc	See MAGNESIUM plus Barium Nitrate, Barium Dioxide and Zinc.

BARIUM NITRIDOOSMATE $Ba(OsNO_3)_2$

(self-reactive)	Barium osmiamate detonates at 150¡C.
	Mellor **15:** 728 (1946-1947).

BARIUM OXIDE BaO

Hydrogen Sulfide	See HYDROGEN SULFIDE plus Soda Lime.
Hydroxylamine	Hydroxylamine is ignited on contact with barium oxide.
	Mellor **8:** 291 (1946-1947).
Nitrogen Dioxide	See NITROGEN TETROXIDE plus Barium Oxide.

BARIUM PERCHLORATE $Ba(ClO_4)_2H_2O$

Alcohols	Reflux heating of an alcohol and barium perchlorate yields a perchloric ester, all of which are highly explosive.
	Kirk and Othmer, Second Ed. **5:** 75 (1963).

BARIUM PEROXIDE BaO_2

Hydroxylamine	Reaction of an aqueous solution of hydroxylamine with barium dioxide causes flaming.
	See also LEAD DIOXIDE plus Hydroxylamine.
	Mellor **3:** 670 (1946-1947).
Magnesium, Zinc and	See MAGNESIUM plus Barium Nitrate,
Barium Nitrate	Barium Dioxide, and Zinc.
Organic Matter	Mixtures of barium peroxide and combustible, organic or readily oxidizable materials are explosive and are ignited easily by friction or on contact with a small amount of water.
	Haz. Chem. Data (1969).

BARIUM RHODANIDE

Sodium Nitrate	A mixture of the two may cause an explosion.
	Pieters, p. 30 (1957).

BARIUM SULFATE $BaSO_4$

Aluminum	See ALUMINUM plus Sulfates.

BARIUM SULFIDE BaS

Chlorine Monoxide	See CHLORINE MONOXIDE plus Calcium Phosphide.
Lead Dioxide	Oxidizing agents like lead dioxide, potassium chlorate and potassium nitrate react vigorously when heated with sulfides of the alkaline earth group.
	Mellor **3:** 745 (1946-1947).
Potassium Chlorate	See BARIUM SULFIDE plus Lead Dioxide.
Potassium Nitrate	See BARIUM SULFIDE plus Lead Dioxide.

BENZALDEHYDE C_6H_5CHO

Performic Acid	See PERFORMIC ACID plus Benzaldehyde.

BENZENE C_6H_6

Bromine Pentafluoride	See BROMINE PENTAFLUORIDE plus Acetic Acid.
Chlorine	See CHLORINE plus Benzene.
Chlorine Trifluoride	See CHLORINE TRIFLUORIDE plus Benzene.
Chromic Anhydride	See CHROMIC ANHYDRIDE plus Benzene.
Nitryl Perchlorate	See NITRYL PERCHLORATE plus Benzene.

Oxygen	See OXYGEN (LIQUID) plus Benzene.
Ozone	See OZONE plus Benzene.
Perchlorates	See PERCHLORATES plus Benzene.
Perchloryl Fluoride and Aluminum Chloride	See PERCHLORYL FLUORIDE plus Benzene and Aluminum Chloride.
Permanganates and Sulfuric Acid	See PERMANGANATES plus Sulfuric Acid and Benzene.
Potassium Peroxide	See SODIUM PEROXIDE plus Aniline.
Silver Perchlorate	See SILVER PERCHLORATE plus Benzene.
	See SILVER PERCHLORATE plus Acetic Acid.
	See SILVER PERCHLORATE plus Toluene.
Sodium Peroxide	See SODIUM PEROXIDE plus Aniline.

BENZENEDIAZONIUM 2-CARBOXYLATE HYDROCHLORIDE $N{\equiv}N\text{-}C_6H_4\text{-}2\text{-}CO_2{\bullet}HCl$

(self-reactive)	An explosion occurred during the transfer of dry crystals.
	H.D. *Embry*, *Chem. Eng. News* **49** (30): 3 (1971). R.M. Stiles et al., *J. Am. Chem. Soc.* **85,** p. 1795 (1963). C.A. Matuszak, *Chem. Eng. News* **49** (24): 39 (1971).

BENZENEDIAZONIUM CHLORIDE C_6H_5NNCl

(self-reactive)	Phenylchlorodiazirine is extremely shock sensitive. It should not be handled in an undiluted state.
	Chem. Eng. News **48** (2): 10 (1970). W.H. Graham, *J. Am. Chem. Soc.* **87:** 4396 (1965). A. Padwa and D. Eastman, *J. Org. Chem.* **34:** 2728 (1969).
Hydrogen Sulfide	An explosive product is obtained when hydrogen sulfide and phenyl diazonium chloride are mixed.

Berichte **15:** 1683.

BENZENESULFONYL CHLORIDE $C_6H_5SO_2Cl$

Dimethyl Sulfoxide	See DIMETHYL SULFOXIDE plus Acyl Halides.
Methylformamide	See METHYL ISONITRILE (self-reactive).

BENZOTRIAZOLE $C_6H_4N_3H$

(self-reactive)

During the vacuum distillation of 2,000 lbs. of benzotriazole in a 500-gallon glass-lined kettle at 160¡ C and a pressure of 2 mm of mercury, the vessel suddenly pressurized, the temperature rose to a recorded 220¡ C, and the contents detonated. This same process had been in trouble-free operation for months.

Chem. Eng. News **34:** 2450 (1956).

BENZOYL CHLORIDE C_6H_5COCl

Dimethyl Sulfoxide	See DIMETHYL SULFOXIDE plus Acyl Halides.
Sodium Azide and Potassium Hydroxide	See SODIUM AZIDE plus Benzoyl Chloride and Potassium Hydroxide.

BENZOYL PEROXIDE $(C_6H_5CO)_2O_2$

(See also DIBENZOYL PEROXIDE)

(self-reactive)

Benzoyl peroxide has been reported to explode for apparently no specific reason. Friction while opening bottles has caused other explosions. Purification of benzoyl peroxide in hot chloroform solutions has also resulted in several explosions. Purification in cold chloroform by addition of methanol is without danger.

Chem. Eng. News **37:** 46 (Jan. 3, 1949).

Chem. Abst. **25:** 4127 (1931).

Carbon Tetrachloride and Ethylene	A reaction of ethylene, carbon tetrachloride and benzoyl peroxide caused an explosion.
	R.O. Bolt, R.M. Joyce, *Chem. Eng. News* **25:** 1866 (1947).
Methyl Methacrylate	Benzoyl peroxide was weighed into a stainless steel beaker that had been rinsed previously with methyl methacrylate. The peroxide catalyzed polymerization of the methacrylate and the build-up of heat was sufficient to ignite the remainder of the peroxide.
	MCA Case History **996** (1964).
Organic Matter	While a bottle of benzoyl peroxide was being opened, it exploded. Organic matter may have been entrapped in the threads of the bottle. When cap was unscrewed, friction caused explosion.
	G.R. Lappin, *Chem. Eng. News* **26:** 3518 (1948).

BENZYL ALCOHOL $C_6H_5CH_2OH$

Acids	See ACIDS plus Benzyl Alcohol.

BENZYL SILANE $C_6H_5CH_2SiH_3$

Air	Benzyl silane is spontaneously flammable in air.
	Lehman and Wilson, p. 53 (1949).

BENZYL SODIUM $C_6H_5CH_2Na$

Air	Benzyl sodium is spontaneously flammable in air.
	Ellern (1961).

BERYLLIUM Be

Carbon Tetrachloride	It has been determined experimentally that a mixture of beryllium powder with carbon tetrachloride or with trichloroethylene will flash or spark on heavy impact.

	ASESB Pot. Incid. **39** (1968).
Lithium	See LITHIUM plus Vanadium.
Phosphorus	The reaction between beryllium and the vapors of phosphorus proceeds with incandescence.
	Mellor **8:** 842 (1946-1947).
Trichloroethylene	See BERYLLIUM plus Carbon Tetrachloride.

BERYLLIUM DIISOPROPYL $(C_3H_7)_2Be$

(See DIISOPROPYL BERYLLIUM)

BERYLLIUM OXIDE BeO

Magnesium	See MAGNESIUM plus Beryllium Oxide.

BERYLLIUM TETRAHYDROBORATE $Be(BH_4)_2$

Air	Beryllium borohydride is spontaneously flammable in air.
	Douda (1966).
Oxygen	See OXYGEN plus Beryllium Borohydride.
Water	See OXYGEN plus Beryllium Borohydride.

BIS (2-CHLOROETHYL) ETHER $ClCH_2CH_2OCH_2CH_2Cl$

Chlorosulfonic Acid	Mixing dichloroethyl ether and chlorosulfonic acid in a closed container caused the temperature and pressure to increase.
	Flynn and Rossow (1970). See Note under complete reference.
Oleum	Mixing dichloroethyl ether and oleum in a closed container caused the temperature and pressure to increase.
	Flynn and Rossow (1970). See Note under complete reference.

BISCYCLOPENTADIENYL MANGANESE

(See MANGANOCENE)

BIS(DIMETHYLSTIBINE) OXIDE $[(CH_3)_2Sb]_2O$

Air	Bisdimethylstibine oxide is spontaneously flammable in air.
	Coates, p. 555 (1956).

BIS(ETHYLAMINO) CYCLOTRISILOXANE

Air	Bisethylamino siloxane is spontaneously flammable in air.
	Douda (1966).

BISMUTH Bi

Aluminum and Air	A mixture of bismuth hydroxide and aluminum hydroxide, coprecipitated, and reduced by hydrogen at 170¡-210¡C, is spontaneously flammable in air at ordinary temperatures.
	Mellor **9:** 626 (1946-1947).
Ammonium Nitrate	See AMMONIUM NITRATE plus Metals (powdered).
Chloric Acid	See ANTIMONY plus Chloric Acid.
Chlorine	Powdered bismuth burns spontaneously in gaseous chlorine. With liquid chlorine, bismuth ignites at 80¡ C.
	Mellor **2:** 92, 95; **9:** 626 (1946-1947).
Iodine Pentafluoride	See ARSENIC plus Iodine Pentafluoride.
Nitric Acid	If fuming nitric acid is poured over powdered bismuth, the

	metal becomes red hot.
	Mellor **9:** 627 (1946-1947).
Perchloric Acid	When bismuth is heated with perchloric acid at 100¡ C or below, the metal dissolves slowly, but at 110¡ a brown coating forms, which on further heating explodes violently.
	J. Am. Chem. Soc. **57:** 817-18 (May 1935).
	ACS **146:** 188.
	The preparation of a salt from these two chemicals is dangerous.
	Mellor **2, Supp. 1:** 613 (1956).

BISMUTHIC ACID $HBiO_3$

Hydrofluoric Acid	When bismuthic acid is treated with 40 per cent hydrofluoric acid at ordinary temperatures, a violent reaction occurs.
	Mellor **9:** 657 (1946-1947).

BISMUTH PENTAFLUORIDE BiF_5

Water	Bismuth pentafluoride reacts violently with water, sometimes with ignition.
	Brauer (1965).

BISMUTH PENTOXIDE Bi_2O_5

Bromine Trifluoride	See BROMINE TRIFLUORIDE plus Bismuth Pentoxide.

BISMUTH TRIBROMIDE $BiBr_3$

Potassium	See POTASSIUM plus Aluminum Bromide.
Sodium	See SODIUM plus Aluminum Bromide.

BISMUTH TRICHLORIDE $BiCl_3$

Potassium	See POTASSIUM plus Aluminum Bromide.
Sodium	See SODIUM plus Aluminum Bromide.

BISMUTH TRIETHYL $(C_2H_5)_3Bi$

(See TRIETHYL BISMUTHINE)

BISMUTH TRIIODIDE BiI_3

Potassium	See POTASSIUM plus Aluminum Bromide.
Sodium	See SODIUM plus Aluminum Bromide.

BISMUTH TRIMETHYL $(CH_3)_3Bi$

(See TRIMETHYL BISMUTHINE)

BISMUTH TRIOXIDE Bi_2O_3

Aluminum	See ALUMINUM plus Bismuth Trioxide.
Chlorine Trifluoride	See CHLORINE TRIFLUORIDE plus Arsenic Trioxide.
Potassium	See POTASSIUM plus Bismuth Trioxide.
Sodium	See SODIUM plus Bismuth Trioxide.

BISMUTH TRIVINYL $(CH_2=CH)_3Bi$

(See TRIVINYL BISMUTHINE)

BIS(TRIFLUOROMETHYL) CHLOROPHOSPHINE $(CF_3)_2PCl$

Air	Bistrifluoromethyl chlorophosphine is spontaneously flammable in air. *Handbook Chem. Phys.*, p. C-428 (1970-1971).

BIS(TRIFLUOROMETHYL) CYANOPHOSPHINE $(CF_3)PCN$

Air	Bistrifluoromethyl cyanophosphine is spontaneously flammable in air. *Handbook Chem. Phys.*, p. C-428 (1970-1971).

BIS(TRIFLUOROMETHYL) PHOSPHINE $(CF_3)_2PH$

Air	Bistrifluoromethyl phosphine is spontaneously flammable in air. *Douda* (1966). *Handbook Chem. Phys.*, p. C-428 (1970-1971).

BORANE-PHOSPHORUS TRIFLUORIDE COMPOUND H_3BPF_3

(self-reactive)	See PHOSPHORUS TRIFLUORIDE plus Diborane.

BORAX $Na_2B_4O_7 \cdot 10H_2O$

Zirconium	See ZIRCONIUM plus Borax.

BORIC ACID $B(OH)_3$

Acetic Anhydride	During an attempt to make triacetyl borate, a mixture of boric acid and acetic anhydride exploded when heated to 58-60¡ C. M. L. Lerner. *Chem. Eng. News.* **51:** (34) (Aug. 20, 1973).
Potassium	See POTASSIUM plus Boric Acid.

BORIC OXIDE B_2O_3

Calcium Oxide and Calcium Chloride	When a mixture of boric oxide and calcium oxide in any proportion is projected into fused calcium chloride, the mass becomes incandescent.

Mellor **5:** 141 (1946-1947).

BORON B

Ammonia	When amorphous boron is heated in dry ammonia, the reaction proceeds with incandescence and hydrogen is evolved.
	Mellor **8:**109 (1946-1947).
Bromine	Boron ignites in bromine vapor at 700¡ C.
	Mellor **5:** 15 (1946-1947).
Bromine Trifluoride	See ANTIMONY plus Bromine Trifluoride.
Cesium Carbide	See SILICON plus Cesium Carbide.
Chlorine	Boron burns spontaneously in gaseous chlorine.
	Mellor **2:** 92, 95; **9:** 626 (1946-1947).
	Boron ignites in chlorine at 410¡ C.
	Mellor **5:** 15 (1946-1947).
Cupric Oxide	Boron reacts violently with cupric oxide after warming, melting glass tubing.
	Mellor **5:** 17 (1946-1947).
Fluorine	Fluorine attacks boron at ordinary temperatures, the mass becoming incandescent.
	Mellor **2:** 12; **5:** 15 (1946-1947).
Iodic Acid	Iodic acid attacks boron below 40¡C. and the mass becomes incandescent.
	Mellor **5:** 15 (1946-1947).
Lead Dioxide	A mixture of boron and lead dioxide explodes violently when ground in a mortar.
	Mellor **5:** 17 (1946-1947).
Nitric Acid	Concentrated nitric acid and boron react so violently that the mass is raised to incandescence.
	Mellor **5:** 16 (1946-1947).

Nitric Oxide	See BORON plus Nitrous Oxide.
Nitrosyl Fluoride	The reaction between nitrosyl fluoride and boron (also phosphorus or silicon) is accompanied by incandescence.
	Z. Anorg. Chemie **47:** 190.
Nitrous Oxide	Amorphous boron ignites when heated in dry nitrous oxide. With nitric oxide, the reaction proceeds with blinding flashes.
	Mellor **8:** 109 (1946-1947).
Potassium Chlorate	The reaction of boron and fused potassium chlorate is vigorous.
	Mellor **5:** 15 (1946-1947).
Potassium Nitrate	Portions of boron powder and potassium nitrate were blended, screened, and placed in aluminum containers. When one of the covered containers was accidentally dropped, there was a flash fire followed by explosions.
	MCA Case History **1334** (1967).
Potassium Nitrite	Molten potassium nitrite is violently decomposed by boron.
	Mellor **5:** 16 (1946-1947).
Rubidium Carbide	See SILICON plus Rubidium Carbide.
Silver Fluoride	Fused silver fluoride reacts explosively with boron at ordinary temperatures.
	Mellor **3:** 389 (1946-1947).
Sulfur	A mixture of boron and sulfur becomes incandescent at 600¡ C.
	Mellor **5:** 15 (1946-1947).

BORON ARSENOTRIBROMIDE BAs_2Br_3

Air	See OXYGEN plus Boron Arsenotribromide.
Oxygen	See OXYGEN plus Boron Arsenotribromide.

BORON BROMODIIODIDE $BBrI_2$

Water	Boron bromodiiodide hydrolyzes violently.
	Mellor **5:** 136 (1946-1947).

BORON DECAHYDRIDE

(See TETRABORANE (10))

BORON DIBROMOIODIDE BBr_2I

Water	Boron dibromoiodide hydrolyzes violently.
	Mellor **5:** 136 (1946-1947).

BORON HEXAHYDRIDE

(See HEXABORANE (10))

BORON NITRIDE BN

Sodium Dioxide	When powdered boron nitride is added to molten sodium dioxide, the reaction proceeds with incandescence.
	Mellor **8:** 111 (1946-1947).

BORON PHOSPHIDE BP

Nitrates	See BORON PHOSPHIDE plus Nitric Acid.
Nitric Acid	Boron phosphide ignites in concentrated nitric acid; with fused alkali nitrates, there is a deflagration.
	Mellor **8:** 845-46 (1946-1947).

BORON PHOSPHODIIODIDE BPI_2

Chlorine	See CHLORINE plus Boron Phosphodiiodide.

Magnesium	See MAGNESIUM plus Boron Phosphodiiodide.
Mercury	See MERCURY plus Boron Phosphodiiodide.

BORON TRIAZIDE $B(N_3)_3$

(self-reactive)	Boron triazide, lithium boroazide, and silicon tetraazide and some of their intermediates are extremely sensitive and explosive.
	Egon Wibergand Horst Michaud, *Z. Naturforsch.* **9b:** 497-500 (1954).

BORON TRIBROMIDE BBr_3

Potassium	See POTASSIUM plus Boron Tribromide.
Sodium	See SODIUM plus Aluminum Bromide.
Water	When boron tribromide and water are mixed, there is an explosion.
	Mellor **5:** 134 (1946-1947). *BCISC* **41**(1962):19 (1970).

BORON TRICHLORIDE BCl_3

Nitrogen Peroxide	Boron trichloride reacts energetically with nitrogen peroxide, phosphine, or fat and grease.
	Mellor **5:** 132 (1946-1947).
Organic Matter	See BORON TRICHLORIDE plus Nitrogen Peroxide.
Oxygen	See OXYGEN plus Boron Trichloride.
Phosphine	See BORON TRICHLORIDE plus Nitrogen Peroxide.

BORON TRI-n-BUTYL $(C_4H_9)_3B$

(See TRIBUTYLBORANE)

BORON TRIFLUORIDE BF_3

Alkali Metals	See ALKALI METALS plus Boron Trifluoride.
Alkaline Earth Metals	See ALKALI METALS plus Boron Trifluoride.
Calcium Oxide	See CALCIUM OXIDE plus Boron Trifluoride.

BORON TRIFLUORIDE ETHERATE $BF_3 \bullet (C_2H_5)_2O$

Lithium Aluminum Hydride	See LITHIUM ALUMINUM HYDRIDE plus Boron Trifluoride Etherate.

BORON TRIIODIDE BI_3

Ammonia	Ammonia reacts with boron triiodide with the development of much heat. *Mellor* **5:** 136 (1946-1947).
Carbohydrates	See BORON TRIIODIDE plus Ethers.
Ethers	Boron triiodide and ethers or carbohydrates react vigorously. *Mellor* **5:** 136 (1946-1947).
Phosphorus	See PHOSPHORUS plus Boron Triiodide.
Phosphoryl Chloride	See PHOSPHORYL CHLORIDE plus Boron Triiodide.

BORON TRIMETHYL $B(CH_3)_3$

(See TRIMETHYLBORANE)

BORON TRIPROPYL $(C_3H_7)_3B$

(See TRIPROPYLBORANE)

BORON TRISULFIDE B_2S_3

Chlorine	See CHLORINE plus Boron Trisulfide.

BRASS

Acetylene	See COPPER plus Acetylene.
Chlorine	See CHLORINE plus Brass.
Hydrogen Peroxide	See IRON plus Hydrogen Peroxide.
Lead Azide	See COPPER plus Lead Azide.

BROMATES

(See also specific bromates as primary entries or see under other reactants)

Acids and Metals (powdered)	See CHLORATES plus Metals (powdered).
Aluminum	See ALUMINUM plus Bromates.
Arsenic	See ARSENIC plus Bromates.
Calcium Hydride	A mixture of calcium hydride and bromates, chlorates or perchlorates explodes violently when rubbed in a mortar. *Mellor* **3:** 651 (1946-1947).
Carbon	See CARBON plus Bromates.
Copper	See COPPER plus Bromates.
Metals (powdered)	See CHLORATES plus Metals (powdered).
Metal Sulfides	See METAL SULFIDES plus Bromates.
Organic Matter	A combination of finely divided organic matter with finely divided bromates (also chlorates or iodates) of barium, calcium, magnesium, potassium, sodium, or zinc can be exploded by heat, percussion, and sometimes, light friction. *Mellor* **2:** 310 (1946-1947). *MCA Case History* **874** (1963).
Phosphonium Iodide	Bromates, chlorates or iodates when dry ignite in phosphonium iodide at ordinary temperatures. *Ann. Chim. et Phys.* (2) **47:** 87.

Phosphorus	See PHOSPHORUS plus Bromates.
Strontium Hydride	A mixture of strontium hydride and bromates, chlorates, or perchlorates explodes violently when rubbed in a mortar.
	Mellor **3:** 651 (1946-1947).
Sulfur	See SULFUR plus Bromates.
Sulfuric Acid and Metals	See CHLORATES plus Metals (powdered).

BROMIC ACID $HBrO_3$

Phosphonium Iodide	See PHOSPHONIUM IODIDE plus Bromic Acid.

BROMIDES

(See specific bromides as primary entries or see under other reactants)

BROMINE Br_2

Acetaldehyde	Combination of acetaldehyde with bromine, chlorine, fluorine, or iodine can be violent.
	Chem. Safety Data Sheet **SD-43** (1952).
Acetylene	Acetylene can react explosively with bromine.
	Von Schwartz, p. 142 (1918).
Acrylonitrile	During the drop-wise addition of bromine into a 500 ml. flask containing acrylonitrile, the periodic cooling with an ice bath was insufficient to prevent a runaway exothermic reaction. When the temperature of the reactants exceeded 40¡ C, the flask exploded.
	MCA Case History **1214** (1966).
Aluminum	See ALUMINUM plus Bromine.
Ammonia	Ammonia plus bromine (with heat) explodes due to the formation of extremely sensitive nitrogen tribromide.
	Mellor **2:** 95 (1946-1947).

Antimony	See ANTIMONY plus Bromine.
Boron	See BORON plus Bromine.
Calcium Nitride	Calcium nitride reacts in the cold with bromine, with incandescence.
	Mellor **8:** 99 (1946-1947).
Cesium Acetylene Carbide	Cesium acetylene carbide burns in the vapors of bromine or iodine.
	Mellor **5:** 844 (1946-1947).
Cesium Monoxide	At ordinary temperatures, cesium monoxide plus bromine, chlorine, fluorine or iodine reacts with incandescence. At temperatures above 150¡C., a blue flame appears with fluorine. Chlorine and iodine act similarly.
	Mellor **2:** 487 (1946-1947).
Chlorotrifluoroethylene and Oxygen	See CHLOROTRIFLUOROETHYLENE plus Bromine and Oxygen.
Copper Hydride	Copper hydride ignites in bromine, chlorine or fluorine.
	Mellor **3:** 73 (1946-1947).
Cuprous Acetylide (Copper Carbide)	Cuprous acetylide is spontaneously flammable with bromine vapor, chlorine gas or fine iodine.
	Mellor **5:** 852 (1946-1947).
Dimethyl Formamide	The use of dimethyl formamide as a solvent in one of the catalysis reactions of olefins and bromine resulted in the operation of a rupture disk on an autoclave. The investigation indicated that there was a highly exothermic reaction between dimethyl formamide and bromine. In one instance mixing 40 cc of bromine and 150 cc of dimethyl formamide resulted in an increase of temperature to above 100¡C and an increase in pressure to above 2000 psi.
	H. A. Tayim and M. Absi, *Chem. & Ind.*, p. 347 (April 21, 1973).
Ethyl Phosphine	A mixture of ethyl phosphine and bromine, chlorine, or nitric acid (fuming) explodes.

	Von Schwartz, pp. 324, 325 (1918).
Fluorine	See FLUORINE plus Bromine.
Germanium	See GERMANIUM plus Bromine.
Hydrogen	Hydrogen and bromine explode.
	Mellor **Supp. I:** 707.
Iron Carbide	See CHLORINE plus Iron Carbide.
Isobutyrophenone	Bromine had been added dropwise at 21-31¡C to a solution of isobutyrophenone in carbon tetrachloride. The flask was then packed in ice. After 15 minutes, the flask exploded.
	MCA Guide for Safety, Appendix 3 (1972).
Lithium	See BROMINE plus Potassium.
Lithium Carbide	Lithium carbide burns vigorously and spontaneously in cold chlorine or fluorine. With bromine or iodine, the materials must be warm.
	Mellor **5:** 848 (1946-1947).
Lithium Silicide	See FLUORINE plus Lithium Silicide.
Magnesium Phosphide	See CHLORINE plus Magnesium Phosphide.
Methyl Alcohol	A violent exothermic reaction of these materials occurred in a measuring cylinder.
	MCA Case History **1863** (1972).
Nickel Carbonyl	The reaction between these liquids proceeds with explosive violence.
	Mellor **2, Supp. 1:** 716 (1956). *J. Am. Chem. Soc.* **48:** 872-82 (1926).
Nitrogen Triiodide	Nitrogen triiodide explodes on contact with bromine, chlorine, or ozone, and is almost instantly decomposed by hydrogen sulfide.
	Champion and Pellet, *Bull. Soc. Chim.* (2) **24:** 447 (1875). *Ann. Chim. et Phys.* (2) **42:** 200.
	E. Schneider, *Report Anal. Chem.* **1:** 54 (1881).
Olefins	See BROMINE plus Dimethyl Formamide.

Oxygen Difluoride	A mixture of oxygen difluoride and bromine or iodine explodes on gentle warming.
	Mellor **2, Supp. 1:** 192 (1956).
Ozone	See OZONE plus Bromine.
Phosphine	Phosphine ignites with bromine or chlorine at room temperature.
	Berichte **3:** 660. *Merck Index,* p. 823 (1968).
Phosphorus	Ordinary phosphorus reacts with gaseous bromine with incandescence. Red phosphorus reacts with bromine (liquid) at ordinary temperatures with incandescence. Small pieces of yellow (white) phosphorus thrown into liquid bromine ignite and cause dangerous explosions.
	Ann. Chim. et Phys. (2) **32:** 337. *Lowig* (1829).
	See also PHOSPHORUS plus Chlorine.
Phosphorus Oxide	See CHLORINE plus Phosphorus Oxide.
Phosphorus Trioxide	Phosphorus trioxide, thrown into a jar of chlorine, ignites immediately and burns with a greenish flame. Phosphorus trioxide reacts violently with liquid bromine — generally ignites.
	Thorpe and Tutton, *J. Chem. Soc.* **59:** 1019 (1891).
Potassium	The reaction between potassium and bromine (gas) is vigorous with incandescence. A violent explosion will occur if potassium is brought in contact with liquid bromine.
	R. Cowper, *Chem. News* **47:** 70 (1883). *Sidgwick*, p. 65 (1950). *Mellor* **2:** 469 (1946-1947). The system bromine-plus-sodium, however, requires a small impact to cause an explosion. The system bromine-plus-lithium requires a much larger impact to explode it.
	H. Staudinger, *Z. Elektrochem.* **31:** 549-52 (1925).
	Mellor **2, Supp. 3:** 1559.
Rubidium Acetylene	Rubidium acetylene carbide burns in cold
Carbide	bromine, chlorine, fluorine, or iodine (vapor).

	Mellor **5:** 849 (1946-1947).
Rubidium Carbide	This carbide burns in bromine gas.
	Mellor **5:** 848 (1946-1947).
Silver Azide	Bromine vapor diluted with some nitrogen plus silver or sodium azides formed bromoazide; explosions often occurred.
	Mellor **8:** 330 (1946-1947).
Sodium	Finely divided sodium reacts with bromine with luminescence. Solid sodium plus liquid bromine can be caused to explode by mechanical shock. See also BROMINE plus Potassium.
	Mellor **Supp. II, Part I:** 714 (1956).
Sodium Acetylene	Sodium acetylene carbide burns in cold chlorine
Carbide	or bromine.
	Mellor **5:** 849 (1946-1947).
Sodium Carbide	Sodium carbide explodes on contact with bromine vapor or water.
	Von Schwartz, p. 328 (1918).
Strontium Phosphide	Mixtures of these materials ignite at about 170¡C.
	Mellor **8:** 841 (1946-1947).
Tin	See TIN plus Bromine.
Uranium Dicarbide	Uranium dicarbide reacts with incandescence with warm fluorine; at 300¡C. with chlorine; or at 390¡C. with bromine.
	Mellor **5:** 890-98 (1946-1947).
Zirconium Dicarbide	Zirconium dicarbide burns in fluorine, in the cold; in chlorine, at 250¡C.; in bromine, at 300¡C.; and in iodine, at 400¡C.
	Mellor **5:** 855-57 (1946-1947).

BROMINE AZIDE N_3Br

(self-reactive)	Spontaneous explosions have been observed with this compound.
	Mellor **8, Supp. 2:** 50 (1967)
	Mellor **8:** 336 (1946-1947).
Antimony	See ANTIMONY plus Bromoazide.
Arsenic	See ANTIMONY plus Bromoazide.
Diethyl Ether	A solution of bromoazide in ether is stable for a few hours, but after a time, or when being concentrated, it is likely to explode on shaking.
	Mellor **8:** 327, 336, 338 (1946-1947).
Phosphorus	See ANTIMONY plus Bromoazide.
Silver	See ANTIMONY plus Bromoazide.
Sodium	See ANTIMONY plus Bromoazide.

BROMINE MONOFLUORIDE BrF

Organic Matter	See BROMINE MONOFLUORIDE plus water.
Water	Halogen fluorides react violently with water and organic compounds.
	Mellor **2, Supp. 1:** 147 (1956).
	See also CHLORINE TRIFLUORIDE plus Elements.

BROMINE PENTAFLUORIDE BrF_5

Acetic Acid	In reactions between bromine pentafluoride and acetic acid, ammonia, benzene, cellulose (in paper), ethyl alcohol, organic matter such as grease or wax, hydrogen sulfide, or methane, fire and explosions are likely.
	Mellor **2, Supp. 1:** 172 (1956).
Ammonia	See BROMINE PENTAFLUORIDE plus Acetic Acid.
Arsenic	See ARSENIC plus Bromine Pentafluoride.
Benzene	See BROMINE PENTAFLUORIDE plus Acetic Acid.

Bromides (Alkaline)	See ARSENIC plus Bromine Pentafluoride.
Cellulose	See BROMINE PENTAFLUORIDE plus Acetic Acid.
Charcoal	See ARSENIC plus Bromine Pentafluoride.
Chlorides (Alkaline)	See ARSENIC plus Bromine Pentafluoride.
Chlorine	See CHLORINE plus Bromine Pentafluoride.
Ethyl Alcohol	See BROMINE PENTAFLUORIDE plus Acetic Acid.
Hydrogen Sulfide	See BROMINE PENTAFLUORIDE plus Acetic Acid.
Iodides (Alkaline)	See ARSENIC plus Bromine Pentafluoride.
Iodine	See ARSENIC plus Bromine Pentafluoride. See IODINE plus Bromine Pentafluoride.
Metallic Halides	See BROMINE PENTAFLUORIDE plus Metal Oxides.
Metal Oxides	Bromine pentafluoride reacts violently with metal oxides and metallic halides. *Mellor* **2, Supp. 1:** 172 (1956).
Metals	See METALS plus Bromine Pentafluoride.
Methane	See BROMINE PENTAFLUORIDE plus Acetic Acid.
Nitric Acid	Bromine pentafluoride reacts violently with strong nitric acid or strong sulfuric acid. *Mellor* **2, Supp. 1:** 172 (1956).
Organic Matter	See BROMINE PENTAFLUORIDE plus Acetic Acid. See also BROMINE MONOFLUORIDE plus Water.
Selenium	See ARSENIC plus Bromine Pentafluoride.
Sulfur	See ARSENIC plus Bromine Pentafluoride.
Sulfuric Acid	See BROMINE PENTAFLUORIDE plus Nitric Acid.
Water	The reaction between bromine pentafluoride and water is very violent. *Mellor* **2, Supp. 1:** 172 (1956). See ARSENIC plus Bromine Pentafluoride. See also BROMINE MONOFLUORIDE plus Water.

BROMINE TRIFLUORIDE BrF_3

(See also other reactants)

Ammonium Bromide	Bromine trifluoride reacts explosively with the following: ammonium bromide, ammonium chloride, ammonium iodide.
	Mellor **2, Supp. 1:** 165 (1956).
Ammonium Chloride	See BROMINE TRIFLUORIDE plus Ammonium Bromide.
Ammonium Iodide	See BROMINE TRIFLUORIDE plus Ammonium Bromide.
Antimony	See ANTIMONY plus Bromine Trifluoride.
Antimonyl Chloride	See BROMINE TRIFLUORIDE plus Antimony Trioxide.
Antimony Trioxide	Bromine trifluoride produces a violent reaction with antimony trioxide, more violent with antimonyl chloride.
	Mellor **2, Supp. 1:** 166 (1956).
Arsenic	See ANTIMONY plus Bromine Trifluoride.
Barium Chloride	Bromine trifluoride rapidly attacks the following salts: barium chloride, cadmium chloride, calcium chloride, cesium chloride, lithium chloride, rubidium chloride, silver chloride.
	Mellor **2, Supp. 1:** 165 (1956).
Bismuth Pentoxide	Bromine trifluoride and bismuth pentoxide, manganous iodate, niobium pentoxide, or tantalum pentoxide react vigorously.
	Mellor **2, Supp. 1:** 166, 173 (1956).
Boron	See ANTIMONY plus Bromine Trifluoride.
Bromine	See ANTIMONY plus Bromine Trifluoride.
Cadmium Chloride	See BROMINE TRIFLUORIDE plus Barium Chloride.
Calcium Chloride	See BROMINE TRIFLUORIDE plus Barium Chloride.
Carbon Monoxide	Bromine trifluoride and carbon monoxide react explosively

	at high temperatures or concentrations.
	Mellor **2, Supp. 1:** 166 (1956).
Carbon Tetrachloride	Bromine trifluoride and carbon tetrachloride react vigorously.
	Mellor **2, Supp. 1:** 167 (1956).
Carbon Tetraiodide	Flaming occurs when bromine trifluoride is dripped onto cooled carbon tetraiodide.
	Mellor **2, Supp. 1:** 166 (1956).
Cesium Chloride	See BROMINE TRIFLUORIDE plus Barium Chloride.
Iodine	See ANTIMONY plus Bromine Trifluoride.
Lithium Chloride	See BROMINE TRIFLUORIDE plus Barium Chloride.
Manganous Iodate	See BROMINE TRIFLUORIDE plus Bismuth Pentoxide.
Metals	See METALS plus Bromine Trifluoride.
Molybdenum	See MOLYBDENUM plus Bromine Trifluoride.
Niobium	See NIOBIUM plus Bromine Trifluoride.
Niobium Pentoxide	See BROMINE TRIFLUORIDE plus Bismuth Pentoxide.
Organic Matter	See BROMINE MONOFLUORIDE plus Water.
Phosphorus	See ANTIMONY plus Bromine Trifluoride.
Platinic Bromide	Both platinic bromide and platinic chloride are vigorously attacked by bromine trifluoride.
	Mellor **2, Supp. 1:** 165 (1956).
Platinic Chloride	See BROMINE TRIFLUORIDE plus Platinic Bromide.
Platinum and Potassium Fluoride	See PLATINUM plus Bromine Trifluoride and Potassium Fluoride.
Potassium Bromide	The following salts are rapidly attacked by bromine trifluoride: potassium bromide, potassium chloride, potassium iodide, rhodium tetrabromide, sodium bromide, sodium chloride, sodium iodide.
	Mellor **2, Supp. 1:** 164 (1956).

Potassium Chloride	See BROMINE TRIFLUORIDE plus Potassium Bromide.
Potassium Iodide	See BROMINE TRIFLUORIDE plus Potassium Bromide.
Rhodium Tetrabromide	See BROMINE TRIFLUORIDE plus Potassium Bromide.
Rubidium Chloride	See BROMINE TRIFLUORIDE plus Barium Chloride.
Silver Chloride	See BROMINE TRIFLUORIDE plus Barium Chloride.
Sodium Bromide	See BROMINE TRIFLUORIDE plus Potassium Bromide.
Sodium Chloride	See BROMINE TRIFLUORIDE plus Potassium Bromide.
Sodium Iodide	See BROMINE TRIFLUORIDE plus Potassium Bromide.
Stannous Chloride	Bromine trifluoride and stannous chloride react with flame.
	Mellor **2, Supp. 1:** 164 (1956).
Sulfur	See ANTIMONY plus Bromine Trifluoride.
Tantalum	See NIOBIUM plus Bromine Trifluoride.
Tantalum Pentoxide	See BROMINE TRIFLUORIDE plus Bismuth Pentoxide.
Tin	See TIN plus Bromine Trifluoride.
Titanium	See MOLYBDENUM plus Bromine Trifluoride.
Tungsten	See MOLYBDENUM plus Bromine Trifluoride.
Uranium Oxides	The reaction between bromine trifluoride and oxides of uranium (UO_2 UO_3, and U_3O_8) is rapid and quantitative below the boiling point of bromine trifluoride.
	Mellor **2, Supp. 1:** 165 (1956).
Vanadium	See MOLYBDENUM plus Bromine Trifluoride.
Water	Bromine trifluoride reacts violently with water.
	Handbook Chem. Phys., **47th Ed.:** B-160 (1966-1967).
	Even at -50¡C., water (present as 6-normal hydrochloric acid) reacted explosively with bromine trifluoride.
	Swanson (1965).
	See BROMINE MONOFLUORIDE plus Water.

BROMOACETYLENE BrC≡CH

Air

During the preparation of solid bromoacetylene an explosion occurred when air was drawn into the Volman trap containing the solid bromoacetylene. Although it was well known that gaseous bromoacetylene reacts violently with oxygen at room temperature, the explosion of the solid material at minus 190¡C was surprising.

Chem. & Ind. (3) (1972).

1-BROMOACETYLENES BrC≡CR

(self-reactive)

The 1-bromoacetylenes should not be distilled. They sometimes explode, even when distilled at reduced pressure.

Rutledge, p. 136 (1968).

p-BROMOBENZOYL ACETANILIDE p-$BrC_6H_4COC_6H_4NHCOCH_3$

Dimethyl Sulfoxide

After a solution of p-bromobenzoyl acetanilide in 600 ml of dimethyl sulfoxide had been heated on a steam bath (100¡C) for 30 minutes, an explosion occurred.

Wischmeyer (1970).

BROMOBENZYL TRIFLUORIDE $BrC_6H_4CF_3$

Magnesium

See MAGNESIUM plus Bromobenzyl Trifluoride.

BROMODIBORANE $BrBH(H_2)BH_2$

Air

This compound burns with a pale green flame in air.

Mellor **5:** 37 (1946-1947).

BROMODIETHYLALUMINUM $(C_2H_5)_2AlBr$

Air

Diethyl aluminum bromide ignites spontaneously in air,

	water, and alcohol.
	Chem. Eng. Progs. **62** (12): 116 (1966).
Alcohol	See DIETHYL ALUMINUM BROMIDE plus Air.
Water	See DIETHYL ALUMINUM BROMIDE plus Air.

2-BROMO-3,5-DIMETHOXYANILINE $NH_2C_6H_2Br(OCH_3)_2$

(self-reactive)	During a laboratory distillation of a mixture of 3, 5-dimethoxyaniline, 2-bromo-3, 5-dimethoxyaniline and dibromo 3,5-dimethoxyaniline an explosion occurred. It was traced to the instability of the brominated compounds.
	Wischmeyer (1970).

BROMOFORM $CHBr_3$

Lithium	See LITHIUM plus Bromoform.
Sodium-Potassium Alloy	See SODIUM-POTASSIUM ALLOY plus Bromoform.

3-BROMO-1-PROPYNE $CH{\equiv}CCH_2Br$

(self-reactive)	Pure propargyl bromide will decompose violently or detonate at temperatures as low as 220¡C.
	Wischmeyer (1966). R. D. Coffee and J. J. Wheeler, *Chem. Eng. Progr. Tech. Man.* **1:** 6-9 (1968).
	Liquid propargyl bromide is easily ignited by impact from such possible sources as "water hammer" or accidental pressurization of the aerated liquid.
	D. R. Forshey, J. C. Cooper, G. H. Martindill and J. M. Kuchta, *Fire Tech.* **5** (2): 100-111 (1969).
Chloropicrin	Tests at the Bureau of Mines showed the mixture to be shock sensitive.
	Forshey, Cooper, Martindill, and Kuchta, *Fire Tech.* **5** (2): 100-111 (1969).

BROMOSILANE SiH_3Br

Air	Bromosilane is spontaneously flammable in air.
	Handbook Chem. Phys., p. B-132 (1970-1971).

BROMOTRICHLOROMETHANE $BrCCl_3$

Ethylene	During the uncatalyzed addition of bromotrichloromethane to ethylene a violent explosion occurred.
	BCISC **33:** 131 (1962).
	Chem. Abst. **57:** 9638 (1953).

BROMOTRIFLUOROMETHANE $CBrF_3$

Aluminum	See ALUMINUM plus Dichlorodifluoromethane.

BRONZE

Hydrogen Peroxide	See IRON plus Hydrogen Peroxide.

BUNA N

Fluorine	See FLUORINE plus Solid Nonmetals and Oxygen.

BUTADIENE CH_2=CHCH=CH_2; CH=C=$CHCH_3$

(see also 1,3-BUTADIENE)

(self-reactive)	Butadiene, when heated under pressure, may undergo violent thermal decomposition.
	Chem. Eng. News **18:** 404 (1940).
Air	In contact with air, butadiene may form violently explosive peroxides, which can be exploded by mild heat or shock. Solid butadiene absorbs enough oxygen at subatmospheric pressures to make it explode violently when heated just

	above its melting point.
	D. G. Hendry, F. R. Hendry and D. Scheutzle, *Ind. Eng. Chem. Prod. Res. Develop.* **7:** 145-151 (1968). D. G. Hendry et al, *Ind. Eng. Chem. Prod. Res. Develop.* **7:** 151-154 (1968). D. S. Alexander, *Ind. Eng. Chem.* **51:** 733 (1959).
Phenol	See PHENOL plus Butadiene.

1, 3-BUTADIENE CH_2=CHCH=CH_2

Chlorine Dioxide	See CHLORINE DIOXIDE plus Butadiene.
Crotonaldehyde	The Diels-Alder reaction between these chemicals under pressure is a logical approach to the preparation of a number of cyclic aldehydes, alcohols, and hydrocarbons. A destructive explosion, including a secondary gas explosion, occurred in carrying out this reaction.
	K. W. Greenlee, *Chem. Eng. News* **26:** 1985 (1948).

BUTADIYNE HC≡CC≡CH

Air	In the preparation of diacetylene by adding 1,4-dichloro-2-butyne to 10% sodium hydroxide and a little dioxane at 100¡C, no difficulty was experienced if the free diacetylene was collected at minus 25¡C and held below that temperature. At temperatures above minus 25¡C explosions would occur.
	Rutledge, pp. 134-135 (1968).

n-BUTANE $CH_3CH_2CH_2CH_3$

Nickel Carbonyl and Oxygen	See NICKEL CARBONYL plus n-Butane and Oxygen.

1-BUTANETHIOL $CH_3(CH_2)_2CH_2SH$

Nitric Acid	See NITRIC ACID plus Organic Matter.

BUTYL ACETATE $C_4H_9OCOCH_3$

Potassium Tert.-Butoxide	See ACETONE plus Potassium Tert.-Butoxide.

t-BUTYL ALCOHOL $(CH_3)_3COH$

Hydrogen Peroxide	See HYDROGEN PEROXIDE plus t-Butyl Peroxide.

t-BUTYL AZIDOFORMATE $(CH_3)_3COCONNN$

Phosgene	In the formation of tert-butyl azidoformate by the addition of phosgene to alcohols followed by the addition of sodium nitride or hydrazoic acid in the presence of pyridine, reaction of phosgene with the azide can cause the formation of explosive carbazide. To prevent the reaction complete removal of excess phosgene is advocated by passing nitrogen into the solution prior to addition of the azide. *Chem. Abst.* **73:** 14099h (1970). *Chem. Phar. Bull.* **18** (4): 850-851 (1970).

BUTYL BORON DICHLORIDE

(See BUTYL DICHLOROBORANE)

BUTYLDICHLOROBORANE $C_4H_9BCl_2$

Air	Butyl boron dichloride is spontaneously flammable in air. *Buls, Bimonthly Rept. 5,* p. 3 (1953).

BUTYL FLUORIDE C_4H_9F

Magnesium Perchlorate	See MAGNESIUM PERCHLORATE plus Butyl Fluoride.

t-BUTYL HYPOCHLORITE $CH_3C(CH_3)_2OCl$

(self-reactive)	Tertiary butyl hypochlorite requires very careful handling to avoid explosive decomposition under relatively mild conditions. At about 25¡C., an ampoule containing 10 grams exploded violently after several minutes exposure to fluorescent and north window light. *Chem. Eng. News* **40** (42): 63 (1962).

t-BUTYL PERACETATE $(CH_3)_3C\text{-}OO\text{-}COCH_3$

(See t-BUTYL PEROXYACETATE)

t-BUTYL PERBENZOATE $(CH_3)_3C\text{-}OO\text{-}COC_6H_5$

(See t-BUTYL PEROXYBENZOATE)

t-BUTYL PEROXYACETATE $(CH_3)_3C\text{-}OO\text{-}COCH_3$

(self-reactive)	t-Butyl peracetate is sensitive to shock and heat. *Haz. Chem. Data*, p. 77 (1973).
Organic Matter	Upon contact with t-butyl peracetate, combustible organic matter can ignite or give rise to an explosion. *Haz. Chem. Data*, p. 77 (1973).

t-BUTYL PEROXYBENZOATE $(CH_3)_3C\text{-}OO\text{-}COC_6H_5$

Organic Matter	Organic substances can ignite or explode upon contact with t-butyl perbenzoate. *Haz. Chem. Data* p. 79 (1973).

BUTYLLITHIUM LiC_4H_9

Air	Butyl lithium above 20% in air can ignite spontaneously if the humidity exceeds 70%. Concentrations above 25% are

	pyrophoric at any humidity.
	S. B. Mirviss *Ind. Eng. Chem.* **53** (1): Supp. 58A-60A (1961). *Handbook Chem. Phys.,* p. C-695 (1970-1971).

BUTYL MERCAPTAN

(See 1-BUTANETHIOL)

BUTYNEDIOL $HOCH_2C{\equiv}CCH_2OH$

Halides	See BUTYNEDIOL plus Hydroxides.
Hydroxides	Pure butynediol is nonexplosive. Small amounts of certain impurities — alkali hydroxides, alkaline earth hydroxides, halides — may cause explosive decomposition upon distillation. Butynediol should not be treated with basic catalysts in the absence of a solvent at room temperature and still less so at elevated temperature; otherwise, uncontrollable decomposition may occur. In strong acids, contamination with mercury salts can also result in violent decomposition.
	Kirk & Othmer, **Supp. II,** First Ed.: 45 (1960).
Mercury Salts and Acid	See BUTYNEDIOL plus Hydroxides.

n-BUTYRALDEHYDE $CH_3(CH_2)_2CHO$

Chlorosulfonic Acid	Mixing n-butyraldehyde and chlorosulfonic acid in a closed container caused the temperature and pressure to increase.
	Flynn and Rossow (1970). See Note under complete reference.
Nitric Acid	Mixing n-butyraldehyde and 70% nitric acid in a closed container caused the temperature and pressure to increase.
	Flynn and Rossow (1970). See Note under complete reference.
Oleum	Mixing n-butyraldehyde and oleum in a closed container

	caused the temperature and pressure to increase.
	Flynn and Rossow (1970). See Note under complete reference.
Sulfuric Acid	Mixing n-butyraldehyde and 96% sulfuric acid in a closed container caused the temperature and pressure to increase.
	Flynn and Rossow (1970). See Note under complete reference.

CADMIUM Cd

Ammonium Nitrate	See AMMONIUM NITRATE plus Metals (powdered).
Hydrazoic Acid	A violent explosion followed immersion of a cadmium rod in hydrazoic acid after about 30 minutes.
	Mellor **8, Supp. 2:** 50 (1967).
Tellurium	See ZINC plus Selenium.
Zinc	See ZINC plus Selenium.

CADMIUM AMIDE $Cd(NH_2)_2$

Water	Cadmium amide, when wetted, heats spontaneously and can explode.
	Mellor **8:** 261 (1946-1947).

CADMIUM AZIDE $Cd(N_3)_2$

(self-reactive)	This is an extremely hazardous substance, exploding when rubbed with a horn spatula.
	Mellor **8, Supp. 2:** 25 (1967).

CADMIUM BROMIDE $CdBr_2$

Potassium	See POTASSIUM plus Aluminum Bromide.

CADMIUM CHLORATE $Cd(ClO_3)_2$

Antimony Sulfide	See CHLORATES plus Antimony Sulfide.
Arsenic Sulfide	See CHLORATES plus Arsenic Sulfide.
Copper Sulfide	See COPPER SULFIDE plus Cadmium Chlorate.
Stannic Sulfide	See STANNIC SULFIDE plus Cadmium Chlorate.
Stannous Sulfide	See STANNOUS SULFIDE plus Cadmium Chlorate.

CADMIUM CHLORIDE $CdCl_2$

Bromine Trifluoride	See BROMINE TRIFLUORIDE plus Barium Chloride.
Potassium	See POTASSIUM plus Aluminum Bromide.

CADMIUM CYANIDE $Cd(CN)_2$

Magnesium	See MAGNESIUM plus Cadmium Cyanide.

CADMIUM DIETHYL $(C_2H_5)_2Cd$

(See DIETHYL CADMIUM)

CADMIUM FLUORIDE CdF_2

Potassium	See POTASSIUM plus Ammonium Bromide.

CADMIUM-HEXAMMINE CHLORATE $Cd(NH_3)_6(ClO_3)_2$

(self-reactive)	This compound detonates when struck. *Mellor* **2, Supp. 1:**592 (1956).

CADMIUM-HEXAMMINE PERCHLORATE $Cd(NH_3)_6\ (ClO_4)_2$

(self-reactive)	This compound detonates when struck, but is less sensitive than hexamminocadmium chlorate.

Mellor **2, Supp. 1:** 592 (1956).

CADMIUM IODIDE CdI_2

Potassium	See POTASSIUM plus Aluminum Bromide.

CADMIUM NITRIDE Cd_3N_2

Acids	Cadmium nitride reacts explosively with dilute acids and bases.
	Mellor **8, Supp. I, Part 1:** 161 (1964).
Bases	See CADMIUM NITRIDE plus Acids.
Water	Cadmium nitride explodes violently in contact with water.
	Mellor **8:** 121, 122, 261 (1946-1947).

CADMIUM OXIDE CdO

Magnesium	See MAGNESIUM plus Beryllium Oxide.

CADMIUM SULFIDE CdS

Iodine Monochloride	See IODINE MONOCHLORIDE plus Cadmium Sulfide.

CADMIUM-TRIHYDRAZINE CHLORATE $Cd(N_2H_4)_3(ClO_3)_2$

(self-reactive)	This compound detonates when struck.
	Mellor **2, Supp. 1:** 592 (1956).

CADMIUM-TRIHYDRAZINE PERCHLORATE

$Cd(H_2NNH_2)_3(ClO_4)_2Cd$

(self-reactive)	This is an extremely explosive salt.
	Mellor **8, Supp. 2:** 88 (1967).

CALCIUM Ca

Acids	Calcium reacts violently with acids.
	Lab. Govt. Chemist (1965).
Air	Finely divided calcium burns spontaneously in air.
	Mellor **3:** 637, 638, 651 (1946-1947).
Chlorine	Finely divided calcium burns spontaneously in chlorine. Solid calcium burns spontaneously in chlorine at elevated temperatures.
	Mellor **3:** 637, 638, 651 (1946-1947).
Chlorine Trifluoride.	Chlorine trifluoride combined with calcium or sodium forms a protective crust, but reaction is violent on heating.
	Mellor **2, Supp. 1:** 156 (1956).
Fluorine	Finely divided or massive calcium burns spontaneously in fluorine at ordinary temperatures.
	Mellor **3:** 637, 638, 651 (1946-1947).
Oxygen	Solid calcium ignites spontaneously in moist oxygen.
	Chem. Eng. News **26:** 1985 (1948).
Silicon	Calcium and silicon react violently if heated to 1,050¡C.
	Mellor **6:** 176, 177 (1946-1947).
Sulfur	A mixture of calcium and sulfur, when ignited, reacts explosively. Calcium burns in sulfur vapor with a brilliant flame. The reaction begins at about 400¡C.
	Perkin and Pratt, *Trans. Faraday Soc.* **3:** 176 (1908).
	Mellor **3:** 639 (1946-1947).
Vanadium Oxide,	A mixture of calcium and vanadium oxide
Sulfur and Water	that was contaminated with sulfur and some moisture caused a severe fire.
	Poole (1971).
Water	Calcium rapidly decomposes water. The heat of reaction is

sufficient that the evolved hydrogen may ignite.

Lab. Govt. Chemist (1965).

CALCIUM ALLOYS

Acids	Calcium alloys react violently with acids.
	Lab. Govt. Chemist (1965).
Water	Calcium alloys rapidly decompose water. The heat of reaction is sufficient that the evolved hydrogen may ignite.
	Lab. Govt. Chemist (1965).

CALCIUM BROMATE $Ca(BrO_3)_2$

Aluminum	See ALUMINUM plus Bromates.
Arsenic	See ARSENIC plus Bromates.
Carbon	See CARBON plus Bromates.
Copper	See COPPER plus Bromates.
Metal Sulfides	See METAL SULFIDES plus Bromates.
Organic Matter	See BROMATES plus Organic Matter.
Phosphorus	See PHOSPHORUS plus Bromates.
Sulfur	See SULFUR plus Bromates.

CALCIUM CARBIDE CaC_2

Hydrogen Chloride	Calcium carbide reacts with hydrogen chloride gas with incandescence.
	Mellor **5:** 862 (1946-1947).
Lead Fluoride	Calcium carbide mixed with lead fluoride, at ordinary temperatures, becomes incandescent.
	Mellor **5:** 862-64 (1946-1947).
Magnesium	See MAGNESIUM plus Calcium Carbide.

Potassium Hydroxide and Chlorine	See DICHLOROACETYLENE plus Air.
Selenium	See SELENIUM plus Calcium Carbide.
Silver Nitrate	See SILVER NITRATE plus Calcium Carbide.
Sodium Peroxide	See SODIUM PEROXIDE plus Calcium Carbide.
Stannous Chloride	See STANNOUS CHLORIDE plus Calcium Carbide.
Sulfur	See SULFUR plus Calcium Carbide.
Water	The reaction between calcium carbide and water can produce enough heat to ignite the acetylene that is formed. G.W. Jones, G.S. Scott, R.E. Kennedy & W.J. Huff, *BM Report Invest.* **3755** (1944). *Von Schwartz*, p. 142 (1918).

CALCIUM CARBONATE $CaCO_3$

Fluorine	See FLUORINE plus Carbonates. See also FLUORINE plus Common Materials and Oxygen.
Magnesium and Hydrogen	See MAGNESIUM plus Hydrogen and Calcium Carbonate.

CALCIUM CHLORATE $Ca(ClO_3)_2$

Aluminum	See ALUMINUM plus Bromates.
Arsenic	See ARSENIC plus Bromates.
Carbon	See CARBON plus Bromates.
Charcoal	See CHLORATES plus Organic Matter.
Copper	See COPPER plus Bromates.
Manganese Dioxide	See CHLORATES plus Manganese Dioxide.
Metal Sulfides	See METAL SULFIDES plus Bromates.
Organic Acids (Dibasic)	See CHLORATES plus Organic Acids.

Organic Matter	See CHLORATES plus Organic Matter.
Phosphorus	See PHOSPHORUS plus Bromates.
Sulfur	See SULFUR plus Bromates.

CALCIUM CHLORIDE $CaCl_2$

Boric Oxide and Calcium Oxide	See BORIC OXIDE plus Calcium Oxide and Calcium Chloride.
Bromine Trifluoride	See BROMINE TRIFLUORIDE plus Barium Chloride.
2-Furan Percarboxylic Acid	See 2-FURAN PERCARBOXYLIC ACID (self-reactive).

CALCIUM CHLORITE $Ca(OCl)_2$

Chlorine	See CHLORINE plus Calcium Chlorite.

CALCIUM HEXAMMONIATE $Ca(NH_3)_6$

Air	Hexammino calcium is spontaneously flammable in air. *Ellern* (1961).

CALCIUM HYDRIDE CaH_2

Air	Calcium hydride burns fiercely in air when heated. *Lab. Govt. Chemist* (1965). NSC *Nat. Saf. News* **77** (2): 37-40 (1958).
Bromates	See BROMATES plus Calcium Hydride.
Chlorates	See BROMATES plus Calcium Hydride.
Perchlorates	See BROMATES plus Calcium Hydride.
Silver Fluoride	See SILVER FLUORIDE plus Calcium Hydride.

CALCIUM HYDROXIDE $Ca(OH)_2$

Maleic Anhydride	See SODIUM HYDROXIDE plus Maleic Anhydride.
Nitroethane	The nitroparaffins, in the presence of water, form salts with inorganic bases. The dry salts are explosive. *Chem. Eng. News* **30:** 2344 (1952).
Nitromethane	See CALCIUM HYDROXIDE plus Nitroethane.
Nitroparaffins	See CALCIUM HYDROXIDE plus Nitroethane.
Nitropropane	See CALCIUM HYDROXIDE plus Nitroethane.
Phosphorus	See PHOSPHORUS plus Alkaline Hydroxides.

CALCIUM HYPOCHLORITE $Ca(OCl)_2$

(See also HYPOCHLORITES)

Amines	Primary amines and calcium hypochlorite or sodium hypochlorite react to form normal chloroamines, which are explosive. *Kirk and Othmer* **1:** 709 (1947).
Anthracene	Anthracene heats on contact with calcium hypochlorite. *Douglas and Thompson* (1949).
Carbon	See CALCIUM HYPOCHLORITE plus Charcoal.
Carbon Tetrachloride	A severe explosion occurred when a carbon tetrachloride fire extinguisher was used to extinguish a fire in an open container of calcium hypochlorite. *NSC Newsletter, Chem. Sec.* (May 1972).
Charcoal	A mixture of equal parts of bleaching powder and finely divided charcoal exploded when heated in a closed vessel. *Halane — Prelim. Info. Sheet* (1953). *Mellor* **2:** 254-62 (1946-1947).
Ethyl Alcohol	A little calcium hypochlorite added to ethyl alcohol or glycerol will result in a violent explosion after a short time. *Roblee* (1966).

Glycerol

When mixed with calcium hypochlorite, glycerol may ignite spontaneously.

H. Fawcett, *Ind. Eng. Chem.* **51:** 89A-90A (1959).

See also CALCIUM HYPOCHLORITE plus Ethyl Alcohol.

Grease or Oil

A metal scoop kept in a drum of calcium hypochlorite was contaminated with grease or oil. Reaction with the contaminant initiated the violent decomposition of the hypochlorite.

MCA Case History **663** (1960).

Hydrochloric Acid

Reaction of these two chemicals releases copious quantities of chlorine gas.

Fawcett (1969).

Iron Oxide

This material has been the cause of many serious accidents caused by explosions in the containers. Oxygen is evolved by reaction between the hypochlorite and oxide catalysts.

A. H. Gill, *Ind. Eng. Chem.* **16:** 577 (1924).

Manganese Oxide

See CALCIUM HYPOCHLORITE plus Iron Oxide.

Mercaptans

Calcium hypochlorite and mercaptans will react violently.

Barrett (1973).

Methyl Carbitol

Fire occurred when a bag of calcium hypochlorite was inadvertently placed on a methyl carbitol spill on the floor.

Wischmeyer (1965).

Nitromethane

Nitromethane, either alone or in a mixture with methanol and castor oil (model airplane fuel) has a delayed but violent reaction with powdered calcium hypochlorite, especially when confined, as in a plastic bag.

H. Fawcett, *Hazards Home Chem.* (1963).

Organic Matter

Calcium hypochlorite contaminated with one per cent of various common organic materials reacted when heated. The reaction varied from mild flame at 350¡F. with wood, to violent explosion at 275¡F. with oil.

Halane — Prelim. Info. Sheet.

Organic Sulfides	Dry calcium hypochlorite when mixed with organic sulfides causes a violent reaction with the possibility of a flash fire.
	Stephenson (1973).
Phenol	This is an exothermic reaction producing toxic fumes, which may ignite.
	H. Fawcett, *Ind. Eng. Chem.* **51:** 89A-90A (1959).
1-Propanethiol	An explosion occurred when 10 grams of calcium hypochlorite was dumped into a beaker containing 5 milliliters of 1-propanethiol. Identical results were obtained with ethanediol and isobutanethiol.
	R. E. Barrett (1973).
Propyl Mercaptan	See CALCIUM HYPOCHLORITE plus Mercaptans.
Sulfur	See SULFUR plus Calcium Hypochlorite.
Turpentine	Calcium hypochlorite was placed in a turpentine can thought to be empty. A few minutes later reaction between the residual turpentine and the calcium hypochlorite resulted in an explosion.
	Benson (1967).

CALCIUM HYPOPHOSPHITE $Ca(H_2PO_2)_2$

Air	Calcium hypophosphite decomposes when heated, forming phosphine, a spontaneously flammable gas in air.
	Mellor **8:** 881 (1946-1947).
Nitric Acid	The salt ignites when nitric acid is poured onto it.
	Mellor **8:** 883 (1946-1947).
Potassium Chlorate	A mixture of calcium hypophosphite and potassium chlorate exploded when being ground with quartz in a mortar. The mixture of calcium hypophosphite and potassium chlorate can be caused to explode by shock, heat, spark or friction.
	Mellor **8:** 881 (1946-1947).

CALCIUM IODATE $Ca(IO_3)_2$

Aluminum	See ALUMINUM plus Bromates.
Arsenic	See ARSENIC plus Bromates.
Carbon	See CARBON plus Bromates.
Copper	See COPPER plus Bromates.
Metal Sulfides	See METAL SULFIDES plus Bromates.
Organic Matter	See BROMATES plus Organic Matter.
Phosphorus	See PHOSPHORUS plus Bromates.
Sulfur	See SULFUR plus Bromates.

CALCIUM-MANGANESE-SILICON

Acids	Calcium-manganese-silicon combinations evolve spontaneously flammable gas when in contact with acids.
	Lab. Govt. Chemist (1965).

CALCIUM NITRIDE Ca_3N_2

Air	Calcium nitride is spontaneously flammable in air.
	Von Schwartz, p. 322 (1918).
Bromine	See BROMINE plus Calcium Nitride.
Chlorine	See CHLORINE plus Calcium Nitride.

CALCIUM OXIDE (QUICKLIME) CaO

Boric Oxide and Calcium Chloride	See BORIC OXIDE plus Calcium Oxide and Calcium Chloride.
Boron Trifluoride	The reaction of calcium oxide and boron trifluoride forms a fused mass after warming.
	Mellor **5:** 123 (1946-1947).

Chlorine Trifluoride	See CHLORINE TRIFLUORIDE plus Aluminum Oxide.
Fluorine	See FLUORINE plus Calcium Oxide.
Hydrofluoric Acid	Liquid hydrofluoric acid and calcium oxide react very violently.
	Mellor **2, Supp. 1:** 129 (1956).
Phosphorus Pentoxide	Calcium oxide or sodium hydroxide reacts with phosphorus pentoxide extremely violently when initiated by local heating.
	Mellor **8, Supp. 3:** 406 (1971).
Water	Addition of water to quicklime has generated temperatures as high as 800¡C. (1,470¡F.). Some reports describe the reaction as violent. Ignition of sulfur, gunpowder, wood, and straw by the heat of the quicklime-water reaction has been reported.
	Mellor **3:** 673 (1946-1947). *Von Schwartz,* p. 325 (1918).

CALCIUM PERCHROMATE $Ca_3(CrOO_3)_2$

(self-reactive)	Calcium perchromate is a buff-colored powder that explodes at 100¡ C.
	Mellor **11:** 359 (1946-1947).

CALCIUM PEROXIDE CaO_2

Polysulfide Polymers	Dry calcium peroxide floating on liquid polysulfide polymers containing mercaptan radicals caused flashing in small scale tests and ignition in plant scale processes.
	R. Davis (1968).

CALCIUM PHOSPHIDE Ca_3P_2

Chlorine	See CHLORINE plus Calcium Phosphide.
Chlorine Monoxide	See CHLORINE MONOXIDE plus Calcium Phosphide.
Hydrochloric Acid	Calcium phosphide and hydrochloric acid undergo a very

	energetic reaction.
	Mellor **8:** 841 (1946-1947).
Oxygen	See SULFUR plus Calcium Phosphide.
Sulfur	See SULFUR plus Calcium Phosphide.
Water	The reaction forms phosphine which is a spontaneously flammable gas (in moist air).
	Von Schwartz, p. 327 (1918). *Lab. Govt. Chemist* (1965). *Douda* (1966).
	Mellor **8:** 841 (1946-1947).

CALCIUM SILICIDE $CaSi_2$

Acids	Calcium silicide plus acids forms the gas, silicon hydride, which may ignite spontaneously in air.
	Lab. Govt. Chemist (1965).
Fluorine	See FLUORINE plus Calcium Silicide.

CALCIUM-SILICON

Acids	Calcium-silicon combinations evolve spontaneously flammable gas when in contact with acids.
	Lab. Govt. Chemist (1965).

CALCIUM SULFATE $CaSO_4$

Aluminum	See ALUMINUM plus Sulfates.

CALCIUM SULFIDE CaS

Lead Dioxide	See BARIUM SULFIDE plus Lead Dioxide.
Potassium Chlorate	See BARIUM SULFIDE plus Lead Dioxide.
Potassium Nitrate	See BARIUM SULFIDE plus Lead Dioxide.

CAMPHOR $C_{10}H_{16}O$

Chromic Anhydride	See CHROMIC ANHYDRIDE plus Naphthalene.

CARBIDES

(See also specific carbides as primary reactants or under other reactants)

Lithium	See LITHIUM plus Carbides.
Oxidizing Agents	Mixtures of carbides and oxidizing agents are explosive.
	Mellor **5:** 848 (1946-1947).
Sulfuric Acid	See SULFURIC ACID plus Carbides.

CARBOHYDRATES

Boron Triiodide	See BORON TRIIODIDE plus Ethers.

CARBON C

Ammonium Nitrate	Explosions may occur when a mixture of these materials is heated.
	Mellor **5:** 822 (1946-1947).
Ammonium Perchlorate	Ammonium perchlorate mixed with carbon (sugar charcoal) undergoes exothermic decomposition below 240¡ C. Above 240¡, the reaction produces mild explosions.
	Trans. Faraday Soc. **56:** 581-90 (1960).
Barium Bromate	See CARBON plus Bromates.
Barium Chlorate	See CARBON plus Bromates.
Barium Iodate	See CARBON plus Bromates.
Bromates	A combination of finely divided carbon with finely divided bromates (also chlorates or iodates) of barium, calcium, magnesium, potassium, sodium, or zinc will explode with

	heat, percussion, and sometimes light friction.
	Mellor **2:** 310 (1946-1947).
Calcium Bromate	See CARBON plus Bromates.
Calcium Chlorate	See CARBON plus Bromates.
Calcium Hypochlorite	See CALCIUM HYPOCHLORITE plus Charcoal.
Calcium Iodate	See CARBON plus Bromates.
Chlorates	See CARBON plus Bromates.
Chlorine	See CHLORINE plus Carbon (Activated).
Chlorine and Chromyl Chloride	See CHLORINE plus Chromyl Chloride and Carbon.
Chlorine Monoxide	There is an immediate explosion when charcoal is added to chlorine monoxide.
	Mellor **5:** 824 (1946-1947).
Fluorine	See FLUORINE plus Carbon.
2-Furan Percarboxylic Acid	See 2-FURAN PERCARBOXYLIC ACID (self-reactive).
Iodates	See CARBON plus Bromates.
Iodine Pentoxide	Iodine pentoxide reacts explosively when warmed with carbon, sulfur, sugar, resin, or powdered combustible elements.
	Mellor **2:** 295 (1946-1947).
Lead Nitrate	Lead nitrate reacts with brilliant sparks when projected on red-hot carbon.
	Mellor **7:** 863 (1946-1947).
Magnesium Bromate	See CARBON plus Bromates.
Magnesium Chlorate	See CARBON plus Bromates.
Magnesium Iodate	See CARBON plus Bromates.
Mercurous Nitrate	At high temperature, a mixture of mercurous nitrate and carbon decomposes explosively.

	Mellor **4:** 987 (1946-1947).
Nitric Acid	Pulverized carbon reacts violently with nitric acid.
	Pascal **10:** 504 (1931-1934).
Oils and Air	Fatty oils are spontaneously flammable when distributed in activated carbon. The carbon enormously increases the surface of oil exposed to the air.
	C. W. Bahme, *NFPA Quarterly* **45:** 341 (1952).
	Von Schwartz, p. 326 (1918).
Potassium and Air	See POTASSIUM plus Carbon and Air.
Potassium Bromate	See CARBON plus Bromates.
Potassium Chlorate	See CARBON plus Bromates.
Potassium Iodate	See CARBON plus Bromates.
Sodium Bromate	See CARBON plus Bromates.
Sodium Chlorate	See CARBON plus Bromates.
Sodium Iodate	See CARBON plus Bromates.
Sodium Sulfide	Mixtures of sodium sulfide and carbon are susceptible to spontaneous heating.
	C. A. Browne, *USDA Tech. Bull.* **141** (1929).
	J. Creevy, *Chem. Age* **44:** 257 (1941).
Zinc Bromate	See CARBON plus Bromates.
Zinc Chlorate	See CARBON plus Bromates.
Zinc Iodate	See CARBON plus Bromates.
Zinc Nitrate	Zinc nitrate explodes when sprinkled on hot carbon.
	Mellor **4:** 655 (1946-1947).

CARBONATES

(See also specific carbonates under other reactants)

Aluminum	See ALUMINUM plus Sodium Carbonate.

Fluorine	See FLUORINE plus Carbonates.
Magnesium	See MAGNESIUM plus Carbonates.
Silicon	See SILICON plus Alkali Carbonates.

CARBON DIOXIDE CO_2

Aluminum and Sodium Peroxide	See ALUMINUM plus Sodium Peroxide and Carbon Dioxide.
Cesium Monoxide	See CESIUM MONOXIDE plus Carbon Dioxide.
Diethyl Magnesium	See DIETHYL MAGNESIUM plus Air.
Lithium	See LITHIUM plus Oxygen. See LITHIUM plus Water.
Lithium Acetylene Carbide Diammino	See LITHIUM ACETYLENE CARBIDE DIAMMINO plus Carbon Dioxide.
Magnesium and Sodium Peroxide	See MAGNESIUM plus Sodium Peroxide and Carbon Dioxide.
Potassium	See POTASSIUM plus Carbon Dioxide.
Potassium Acetylene Carbide	See POTASSIUM ACETYLENE CARBIDE plus Carbon Dioxide.
Sodium	See SODIUM plus Carbon Dioxide.
Sodium Carbide	See SODIUM CARBIDE plus Carbon Dioxide.
Sodium-Potassium Alloy	See SODIUM-POTASSIUM ALLOY plus Carbon Dioxide.
Titanium	See TITANIUM plus Carbon Dioxide.

CARBON DISULFIDE CS_2

Aluminum	See ALUMINUM plus Carbon Disulfide.
Azides	Carbon disulfide plus any of the azides produces violently

	explosive, extremely sensitive salts.
	Mellor **8:** 338 (1946-1947).
Cesium Azide	See CARBON DISULFIDE plus Azides.
Chlorine	See CHLORINE plus Carbon Disulfide.
Chlorine Monoxide	See CHLORINE MONOXIDE plus Carbon Disulfide.
Ethylene Diamine	Mixing carbon disulfide and ethylene diamine in a closed container caused the temperature and pressure to increase.
	Flynn and Rossow (1970). See Note under complete reference.
Ethyleneimine	Mixing carbon disulfide and ethyleneimine in a closed container caused the temperature and pressure to increase.
	Flynn and Rossow (1970). See Note under complete reference.
Fluorine	See FLUORINE plus Carbon Disulfide.
Lead Azide	See CARBON DISULFIDE plus Azides.
Lithium Azide	See CARBON DISULFIDE plus Azides.
Nitric Oxide	See NITRIC OXIDE plus Carbon Disulfide.
Nitrogen Dioxide	See NITROGEN TETROXIDE plus Carbon Disulfide.
Permanganates and Sulfuric Acid	See PERMANGANATES plus Sulfuric Acid and Benzene.
Potassium	See POTASSIUM plus Carbon Disulfide.
Potassium Azide	See CARBON DISULFIDE plus Azides.
Rubidium Azide	See CARBON DISULFIDE plus Azides.
Sodium Azide	See CARBON DISULFIDE plus Azides.
Zinc	See ZINC plus Carbon Disulfide.

CARBON MONOXIDE CO

Bromine Trifluoride	See BROMINE TRIFLUORIDE plus Carbon Monoxide.
Cesium Monoxide	See CESIUM MONOXIDE plus Carbon Dioxide.

Chlorine Trifluoride	See CHLORINE TRIFLUORIDE plus Ammonia.
Iodine Heptafluoride	See IODINE HEPTAFLUORIDE plus Carbon Monoxide.
Lithium and Water	See LITHIUM plus Carbon Monoxide and Water.
Nitrogen Trifluoride	See HYDROGEN plus Nitrogen Trifluoride.
Oxygen	See OXYGEN (LIQUID) plus Carbon Monoxide.
Oxygen Difluoride	See HYDROGEN plus Oxygen Difluoride.
Potassium and Oxygen	See POTASSIUM plus Carbon Monoxide and Oxygen.
Silver Oxide	See SILVER OXIDE plus Carbon Monoxide.
Sodium and Ammonia	See SODIUM plus Carbon Monoxide and Ammonia.

CARBON TETRABROMIDE CBr_4

Lithium	See LITHIUM plus Bromoform.

CARBON TETRACHLORIDE CCl_4

Allyl Alcohol	See ALLYL ALCOHOL, plus Carbon Tetrachloride.
Aluminum	See ALUMINUM plus Carbon Tetrachloride.
Aluminum Triethyl Sesquichlorides	See ALUMINUM TRIETHYL plus Carbon Tetrachloride.
Barium	See BARIUM plus Carbon Tetrachloride.
Benzoyl Peroxide and Ethylene	See BENZOYL PEROXIDE plus Carbon Tetrachloride and Ethylene.
Beryllium	See BERYLLIUM plus Carbon Tetrachloride.
Bromine Trifluoride	See BROMINE TRIFLUORIDE plus Carbon Tetrachloride.
Calcium Hypochlorite	See CALCIUM HYPOCHLORITE plus Carbon Tetrachloride.
Diborane	A violent explosion occurred when carbon tetrachloride was used on a borane fire.

	Fawcett (1973).
Dimethyl Formamide	See DIMETHYL FORMAMIDE plus Carbon Tetrachloride.
Disilane	See DISILANE plus Carbon Tetrachloride.
Ethylene	Ethylene and carbon tetrachloride can react explosively under high pressures in the presence of organic peroxide catalysts.
	R. O. Bolt, *Chem. Eng. News* **25:** 1866 (1947).
	R. M. Joyce, *Chem. Eng. News* **25:** 1866-7 (1947).
Fluorine	See FLUORINE plus Carbon Tetrachloride.
Lithium	See LITHIUM plus Trichlorotrifluoroethane.
	See LITHIUM plus Carbon Tetrachloride.
Magnesium	See ALUMINUM plus Chloroform.
Oxygen (Liquid)	See OXYGEN (LIQUID) plus Chlorinated Hydrocarbons.
Plutonium	See PLUTONIUM plus Carbon Tetrachloride.
Potassium	See POTASSIUM plus Carbon Tetrachloride.
	See POTASSIUM plus Boron Tribromide.
Potassium Tert.-Butoxide	See ACETONE plus Potassium Tert.-Butoxide.
Silver Perchlorate and Hydrochloric Acid	See SILVER PERCHLORATE plus Carbon Tetrachloride and Hydrochloric Acid.
Sodium	See SODIUM plus Carbon Tetrachloride.
	See SODIUM plus Cobaltous Bromide.
Sodium-Potassium Alloy	See SODIUM-POTASSIUM ALLOY plus Carbon Tetrachloride.
Tetrasilane	See TETRASILANE plus Carbon Tetrachloride.
Trisilane	See TRISILANE plus Carbon Tetrachloride.
Uranium	See URANIUM plus Carbon Tetrachloride.
Wax	An explosion occurred when a stream of carbon tetrachloride (fire extinguisher) was directed on burning

	wax.
	Chem. Eng. News **25:** 1866, 2852 (1947).
	Chem. Eng. News **26:** 957 (1948).
Zirconium	See ZIRCONIUM plus Carbon Tetrachloride.

CARBON TETRAIODIDE CI_4

Bromine Trifluoride	See BROMINE TRIFLUORIDE plus Carbon Tetraiodide.

CARO'S ACID H_2SO_5

(See PERMONOSULFURIC ACID plus second reactant)

CAUSTIC POTASH KOH

(See POTASSIUM HYDROXIDE plus second reactant)

CAUSTIC SODA NaOH

(See SODIUM HYDROXIDE plus second reactant)

CELLULOSE $(C_6H_{12}O_5)_\chi$

Bromine Pentafluoride	See BROMINE PENTAFLUORIDE plus Acetic Acid.
Fluorine	See FLUORINE plus Cellulose.
Hydrogen Peroxide	See HYDROGEN PEROXIDE plus Cellulose.
Sodium Hypochlorite	See SODIUM HYPOCHLORITE plus Oxalic Acid.
Sodium Nitrite	See SODIUM NITRITE plus Cellulose.

CERIUM Ce

Air	See RARE EARTH METALS plus Air.
Halogens	See RARE EARTH METALS plus Halogens.

Phosphorus	Cerium or lanthanum and phosphorus react violently at 400¡ - 500¡ C.
	Mellor **8, Supp. 3:** 347, 252 (1971).

CERIUM ALUMINOHYDRIDE

(See CERIUM TETRAHYDROALUMINATE)

CERIUM HYDRIDE CeH_3

Air	Cerium hydride is spontaneously flammable in air.
	Douda (1966).

CERIUM NITRIDE CeN

Acids	Cerium nitride sometimes reacts violently with dilute acids.
	Mellor **8:** 121 (1946-1947).
Air	With moist air, cerium nitride undergoes spontaneous, incandescent oxidation. If a few drops of water are added to the cerium nitride, the heat developed is adequate to ignite the ammonia and hydrogen evolved.
	Mellor **8:** 121 (1946-1947).
Water	The reaction of cerium nitride and water can produce enough heat to ignite the hydrogen and ammonia being evolved.
	Mellor **8:** 121 (1946-1947).

CERIUM TETRAHYDROALUMINATE $Ce(AlH_4)_3$

Air	Cerium aluminohydride is spontaneously flammable in air.
	Chem. Abst. **49:** 766e (1955). J. Aubrey and G. Monnier, *Comp. Rend.* **238:** 2534-2535 (1954).

CEROUS PHOSPHIDE CeP

Water	The reaction of cerous phosphide, lanthanum phosphide, or neodymium phosphide and water liberates spontaneously flammable phosphine.
	Mellor **8, Supp. 3:** 347, 342, 348 (1971).

CESIUM Cs

Air	Cesium is spontaneously flammable in air at room temperature, if the surface of the cesium is clean.
	Mellor **2:** 468 (1946-1947).
Chlorine	Chlorine vapors and cesium, lithium, or rubidium react with luminous flame.
	Mellor **2, Supp. 1:** 380 (1956).
Oxygen	Cesium burns spontaneously in dry oxygen.
	Mellor **2:** 468 (1946-1947).
Phosphorus	See PHOSPHORUS plus Cesium.
Water	At 20¡C. the heat of reaction is adequate to ignite the hydrogen liberated in the reaction between water and cesium.
	Mellor **2:** 469 (1946-1947).

CESIUM ACETYLIDE CsC_2H

Arsenic	See ARSENIC plus Cesium Acetylene Carbide.
Bromine	See BROMINE plus Cesium Acetylene Carbide.
Chlorine	See CHLORINE plus Cesium Acetylene Carbide.
Cupric Oxide	Cesium acetylene carbide explodes on contact with lead dioxide or cupric oxide at 350¡C.
	Mellor **5:** 849 (1946-1947).
Fluorine	See CHLORINE plus Cesium Acetylene Carbide.
	See FLUORINE plus Cesium Acetylene Carbide.
Hydrogen Chloride	Cesium acetylene carbide burns in hydrogen chloride gas.

	Mellor **5:** 849 (1946-1947).
Iodine	See IODINE plus Cesium Acetylene Carbide.
Lead Dioxide	See CESIUM ACETYLENE CARBIDE plus Cupric Oxide.
Nitrogen Dioxide	Cesium acetylene carbide ignites at about 100¡C. in nitrogen dioxide.
	Mellor **5:** 848-50 (1946-1947).
Phosphorus	See PHOSPHORUS plus Cesium Acetylene Carbide.
Sulfur Dioxide	Cesium acetylene carbide reacts with sulfur dioxide at ordinary temperatures, with incandescence.
	Mellor **5:** 848-50 (1946-1947).
Sulfuric Acid	Cesium acetylene carbide burns with sulfuric acid.
	Mellor **5:** 849 (1946-1947).

CESIUM AMIDE $CsNH_2$

Water	The reaction between cesium amide and water in the presence of air proceeds with incandescence.
	Mellor **8:** 256 (1946-1947).

CESIUM AZIDE CsN_3

(self-reactive)	Cesium azide decomposes at 326¡ C.
	Mellor **8, Supp. 2:** 43 (1967).
Carbon Disulfide	See CARBON DISULFIDE plus Azides.

CESIUM CARBIDE Cs_2C_2

Boron	See SILICON plus Cesium Carbide.
Ferric Oxide	Ferric oxide is reduced with incandescence when gently heated with cesium carbide.
	Mellor **5:** 849 (1946-1947).

Hydrochloric Acid	Cesium carbide ignites in contact with hydrochloric acid unless the acid is dilute.
	Mellor **5:** 848 (1946-1947).
Iodine	See IODINE plus Cesium Carbide.
Nitric Acid	A mixture of nitric acid and cesium carbide will explode.
	Mellor **5:** 848 (1946-1947).
Silicon	See SILICON plus Cesium Carbide.

CESIUM CHLORIDE CsCl

Bromine Trifluoride	See BROMINE TRIFLUORIDE plus Barium Chloride.

CESIUM FLUORIDE NITROSYL FLUORIDE COMPLEX $CsF.HNF_2$

(self-reactive)	This complex is an unstable compound at room temperature.
	Lawless and Smith, pp. 39, 76 (1968).

CESIUM HEXAHYDROALUMINATE Cs_3AlH_6

(self-reactive)	See POTASSIUM HEXAHYDROALUMINATE (self-reactive).

CESIUM HYDRIDE CsH

Acetylene	In the presence of moisture, cesium hydride reacts vigorously, even at -60¡C. When dry, no reaction occurs below 42¡C.
	Mellor **2:** 483 (1946-1947).
Oxygen	See OXYGEN plus Cesium Hydride.

CESIUM MONOXIDE Cs_2O

Bromine	See BROMINE plus Cesium Monoxide.

Carbon Dioxide	When heated, cesium monoxide burns in carbon monoxide or carbon dioxide.
	Mellor **2:** 487 (1946-1947).
Carbon Monoxide	See CESIUM MONOXIDE plus Carbon Dioxide.
Chlorine	See BROMINE plus Cesium Monoxide.
Fluorine	See BROMINE plus Cesium Monoxide.
Iodine	See BROMINE plus Cesium Monoxide.
Sulfur Dioxide	Sulfur dioxide bleaches cesium monoxide at ordinary temperatures, and when heated the reaction is attended by incandescence.
	Mellor **2:** 487 (1946-1947).
Water	Cesium monoxide is spontaneously flammable in air.
	Brauer (1965).

CESIUM NITRIDE Cs_3N

Air	Cesium nitride burns in air and is readily attacked by chlorine, phosphorus, or sulfur.
	Mellor **8:** 99, 101 (1946-1947).
Chlorine	See CESIUM NITRIDE plus Air.
Phosphorus	See CESIUM NITRIDE plus Air.
Sulfur	See CESIUM NITRIDE plus Air.

CESIUM PERFLUOROPROPOXIDE $CsOC_3F_7$

Fluorine	See FLUORINE plus Cesium Perfluoropropoxide.

CESIUM PHOSPHIDE Cs_3P

Water	Cesium phosphide reacts with water or moist air instantaneously to yield spontaneously flammable phosphine.

	Van Wazer (1958).

CESIUM SILICIDE Cs_2Si_2

Water	The silicides of cesium, potassium, rubidium, and sodium ignite explosively in contact with water.
	Ellern, p. 29 (1968). *Brauer* (1965).

CHARCOAL C

(See also CARBON)

Air	Charcoal is spontaneously flammable when freshly calcined.
	Von Schwartz, p. 323 (1918).
Air (Liquid)	Explosions may occur when liquid air contacts organic matter. A cracked tube containing activated charcoal, when immersed in liquid air, caused a violent explosion.
	J. Taylor, *J. Sci. Instr.* **5:** 24 (1928).
Barium Chlorate	See CHLORATES plus Organic Matter.
Bromine Pentafluoride	See ARSENIC plus Bromine Pentafluoride.
Calcium Chlorate	See CHLORATES plus Organic Matter.
Calcium Hypochlorite	See CALCIUM HYPOCHLORITE plus Charcoal.
Chlorine Monoxide	See CHLORINE MONOXIDE plus Charcoal.
Chlorine Trifluoride	See CHLORINE TRIFLUORIDE plus Charcoal.
Fluorine	See FLUORINE plus Common Materials and Oxygen.
Hydrogen Peroxide	See HYDROGEN PEROXIDE plus Charcoal.
Magnesium Chlorate	See CHLORATES plus Organic Matter.
Oxygen and Wood	See OXYGEN (LIQUID) plus Wood and Charcoal.
Perchlorates	See PERCHLORATES plus Charcoal.
Perchloric Acid	See PERCHLORIC ACID plus Charcoal.

Peroxides	See SODIUM PEROXIDE plus Aniline.
Phosphorus and Air	See PHOSPHORUS plus Charcoal and Air.
Potassium	See POTASSIUM plus Charcoal.
Potassium Chlorate	See CHLORATES plus Organic Matter.
Potassium Nitrate	See POTASSIUM NITRATE plus Ammonium Chloride.
Potassium Perchlorate	See PERCHLORATES plus Charcoal.
Ruthenium Tetroxide	See RUTHENIUM TETROXIDE plus Charcoal.
Silver Nitrate	See SILVER NITRATE plus Charcoal.
Sodium Chlorate	See CHLORATES plus Organic Matter.
Sodium Peroxide	See SODIUM PEROXIDE plus Aniline.
Sodium Peroxide and Silver Chloride	See SODIUM PEROXIDE plus Silver Chloride and Charcoal.
Sulfur	See SULFUR plus Charcoal.
Sulfur and Sodium Nitrate	See SULFUR plus Sodium Nitrate and Charcoal.
Zinc Chlorate	See CHLORATES plus Organic Matter. See ZINC CHLORATE plus Charcoal.

CHLORATES

(See also specific chlorates as primary entries and under other reactants)

Acids	All chlorates, when brought in contact with sulfuric acid or certain other strong acids, may give off chlorine dioxide, an explosive gas (See CHLORINE DIOXIDE, self-reactive). With concentrated sulfuric acid, a violent explosion is usual. *Latimer and Hildebrand* (1940). *Von Schwartz*, p. 323 (1918). Also see CHLORATES plus Organic Acids.
Acids and Metals	See CHLORATES plus Metals (powdered).

(powdered)	
Aluminum	See ALUMINUM plus Bromates.
Antimony Sulfide	Antimony sulfide reacts with incandescence with chlorates of cadmium, magnesium, or zinc.
	Mellor **Supp. II, Part I:** 584 (1956).
	A mixture of chlorates plus antimony sulfide, cyanides or thiocyanates explodes. The reaction may be caused by heat, shock, or friction.
	Von Schwartz, p. 323 (1918). *Pieters,* p. 30 (1957).
Arsenic	See ARSENIC plus Bromates.
Arsenic Sulfide	Arsenic sulfide reacts with incandescence with chlorates of cadmium, magnesium, or zinc.
	Mellor **Supp. II, Part I:** 584 (1956).
Calcium Hydride	See BROMATES plus Calcium Hydride.
Carbon	See CARBON plus Bromates.
Charcoal	See CHLORATES plus Organic Matter.
Copper	See COPPER plus Bromates.
Copper Sulfide	See COPPER SULFIDE plus Cadmium Chlorate.
Cyanides	See CHLORATES plus Antimony Sulfide.
	See CYANIDES plus Chlorates. See POTASSIUM CYANIDE plus Sodium Chlorate.
Manganese Dioxide	A mixture of manganese dioxide plus chlorates of barium, calcium, magnesium, potassium, sodium, or zinc may liberate oxygen and heat explosively. The reaction may be originated by heat, shock, friction, age, or static electricity.
	Chem. Eng. News **30:** 3210. *Von Schwartz,* p. 323 (1918).
Mercury Tetratriphosphide	See MERCURY TETRATRIPHOSPHIDE plus Air.
Metals (powdered)	Some mixtures of chlorates and bromates with combustible substances, including powdered metals, are likely to ignite by friction or percussion. Strong acids have a very violent action on these substances and many mixtures of chlorates and combustible substances are set on fire if acted on by

	strong sulfuric acid.
	Lab. Govt. Chemist (1965).
Metal Sulfides	See METAL SULFIDES plus Bromates. See COPPER SULFIDE plus Cadmium Chlorate.
	See CHLORATES plus Antimony Sulfide.
Organic Acids	When a mixture of chlorates and organic acids
(Dibasic)	is heated above room temperature, explosive chlorine dioxide is evolved.
	U.S. Pat. 2,338,268 (1944).
Organic Matter	A mixture of organic matter plus barium chlorate, calcium chlorate, magnesium chlorate, potassium chlorate, sodium chlorate, or zinc chlorate may liberate oxygen and heat explosively. A similar reaction occurs when manganese dioxide, sulfur, or charcoal is combined with these chlorates.
	Chem. Eng. News **30:** 3210. *Von Schwartz,* p. 323 (1918).
Phosphonium Iodide	See PHOSPHONIUM IODIDE plus Bromates.
Phosphorus	See PHOSPHORUS plus Bromates.
	See PHOSPHORUS plus Chlorates.
Potassium Cyanide	A mixture of potassium cyanide and chlorates reacts explosively.
	Bahme, p. 30 (1961).
Selenium	See SELENIUM plus Chlorates.
Sodium Hypophosphite	Mixtures of sodium hypophosphite and chlorates or nitrates will explode if moistened, then dried slowly over flame.
	Chem. Eng. News **25:** 3176-77 (1947).
Strontium Hydride	See BROMATES plus Strontium Hydride.
Sulfur	See SULFUR plus Chlorates. See CHLORATES plus Organic Matter.
Sulfur and Copper	See SULFUR plus Chlorates and Copper.
Sulfur Dioxide	Dry sulfur dioxide reacts on chlorates with evolution of chlorine peroxide which will flash at 60¡C. and can

	explode.
	Mellor **10:** 217 (1946-1947).
Sulfuric Acid	See CHLORATES plus Acids. See also SULFURIC ACID plus Carbides. See SODIUM CHLORATE plus Sulfuric Acid.
	The reaction of chlorates and sulfuric acid (to form chlorine dioxide) may cause explosions.
	Mellor **2, Supp. 1:** 521 (1956).
Sulfuric Acid and Metals	See CHLORATES plus Metals (powdered).
Thiocyanates	See THIOCYANATES plus CHLORATES.
	See CHLORATES plus Antimony Sulfide.
Zinc	See ZINC plus Chlorates.

CHLORIC ACID $HClO_3$

(self-reactive)	Concentrations of chloric acid above 40% decompose.
	Mellor **2, Supp. 1:** 576 (1956).
Ammonia	See ANTIMONY plus Chloric Acid.
Antimony	See ANTIMONY plus Chloric Acid.
Antimony Sulfide	See ANTIMONY SULFIDE plus Chloric acid.
Arsenic Sulfide	See ARSENIC SULFIDE plus Chloric Acid.
Bismuth	See ANTIMONY plus Chloric Acid.
Copper Sulfide	See COPPER SULFIDE plus Cadmium Chlorate.
Organic Matter	Chloric acid decomposes many organic substances with spontaneous ignition.
	Mellor **2:** 310 (1946-1947).
	See ANTIMONY plus Chloric Acid.
Phosphonium Iodide	See PHOSPHONIUM IODIDE plus Bromic Acid.

Stannic Sulfide	See STANNIC SULFIDE plus Chloric Acid.
Stannous Sulfide	See STANNOUS SULFIDE plus Chloric Acid.

CHLORIDES

(See specific chlorides as primary entries or under other reactants)

CHLORINATED HYDROCARBONS

Aluminum	See ALUMINUM plus Chlorinated Hydrocarbons.
Oxygen (liquid)	See OXYGEN (LIQUID) plus Chlorinated Hydrocarbons.
Potassium	See POTASSIUM plus Chlorinated Hydrocarbons.
Sodium	See SODIUM plus Chlorinated Hydrocarbons.

CHLORINATED POLYETHYLENE

Fluorine	See FLUORINE plus Solid Nonmetals and Oxygen.

CHLORINE Cl_2

Acetaldehyde	See BROMINE plus Acetaldehyde.
Acetylene	Acetylene can react explosively with chlorine.
	Von Schwartz, p. 142 (1918).
Alcohols	See ALCOHOLS plus Hypochlorous Acid.
Alkylisothiourea Salts	On long contact or with excess chlorine, explosions occur due to the formation of unstable nitrogen trichloride.
	J. Am. Chem. Soc. **63:** 3520 (1941).
Alkylphosphines	Unless precautions are taken, the reaction of chlorine with alkylphosphines or dialkylphosphines is a vigorous decomposing reaction.
	Mellor **8, Supp. 3:** 900 (1971).
Aluminum	See ALUMINUM plus Chlorine.

Ammonia	Ammonia plus chlorine (with heat) explodes due to the formation of extremely sensitive nitrogen trichloride. Excess chlorine (without heat) reacts similarly.
	Mellor **2:** 95 (1946-1947). *Mathieson Chlorine* (1948).
	Mellor **8, Supp. 2:** 330 (1964).
Antimony	See ANTIMONY plus Chlorine.
Arsenic	See ARSENIC plus Chlorine.
Arsenic Disulfide	Arsenic disulfide ignites in a rapid stream of chlorine.
	Mellor **9:** 270 (1946-1947).
Arsine	When chlorine is bubbled into arsine, each bubble produces a flame.
	Mellor **9:** 55 (1946-1947).
	Mellor **2, Supp. 1:** 379 (1956).
Barium Phosphide	The phosphide ignites in chlorine at 90¡ C.
	Mellor **8, Supp. 3:** 842 (1971).
Benzene	An explosion of benzene vapors and chlorine (inadvertently mixed) was initiated by light.
	Report, Amer. Potash and Chemical Co.
Bismuth	See BISMUTH plus Chlorine.
Boron	See BORON plus Chlorine.
Boron Phosphodiiodide	Powdered magnesium and boron phosphodiiodide react with incandescence.
	Mellor **8:** 845 (1946-1947).
Boron Trisulfide	Boron trisulfide ignites in chlorine, even if cold.
	Mellor **5:** 144 (1946-1947).
Brass	Brass burns spontaneously in gaseous chlorine.
	Mellor **2:** 95, 292; **9:** 626 (1946-1947).
Bromine Pentafluoride	Mixture of chlorine and bromine pentafluoride explodes on heating.

	Mellor **2, Supp. 1:** 173 (1956).
Calcium	See CALCIUM plus Chlorine.
Calcium Carbide and Potassium Hydroxide	See DICHLOROACETYLENE plus Air.
Calcium Chlorite	The reaction of chlorine and a dilute solution of calcium chlorite evolves explosive chlorine dioxide.
	Mellor **2, Supp. 1:** 382 (1956).
	See also CHLORINE DIOXIDE (self-reactive).
Calcium Nitride	Calcium nitride reacts in the cold with chlorine, with incandescence.
	Mellor **8:** 99 (1946-1947).
Calcium Phosphide	Mixtures of chlorine and calcium phosphide react readily at about 100¡C.
	Mellor **8:** 841 (1946-1947).
Carbon (Activated)	The mixture spontaneously ignites in the dry state.
	Bahme, p. 28 (1961).
Carbon Disulfide	When liquid chlorine was added to carbon disulfide in an iron cylinder, the iron catalyzed an explosive reaction.
	MCA Case History **971** (1964).
Cesium	See CESIUM plus Chlorine.
Cesium Acetylene Carbide	Cesium acetylene carbide burns in cold chlorine or fluorine.
	Mellor **5:** 849 (1946-1947).
Cesium Monoxide	See BROMINE plus Cesium Monoxide.
Cesium Nitride	See CESIUM NITRIDE plus Air.
Chromyl Chloride and Carbon	The reaction of a mixture of chlorine and chromyl chloride with red-hot carbon sometimes causes a violent reaction or explosion.

	Mellor **11:** 395 (1946-1947).
Copper	See COPPER plus Chlorine.
Copper Hydride	See BROMINE plus Copper Hydride.
Cuprous Acetylide	See BROMINE plus Cuprous Acetylide.
Dialkylphosphines	See CHLORINE plus Alkylphosphines.
Diborane	Diborane explodes in contact with chlorine at ordinary temperatures.
	Mellor **5:** 37 (1946-1947).
Dibutyl Phthalate	See CHLORINE plus Polypropylene.
Diethyl Ether	When ether is poured into chlorine gas an explosion results.
	Bernthsen (1912).
Diethyl Zinc	Diethyl zinc is spontaneously flammable in air or chlorine.
	Handbook Chem. Phys., p. C-715 (1970-1971).
Drawing Wax	See CHLORINE plus Polypropylene
Ethane	Chlorine and ethane have produced explosions.
	Chem. Abst. **31:** 85025 (1937). W. W. Lawrence and S. E. Cook, *Ind. Eng. Chem. Proc. Dev.* **9** (1): 47-49 (1970).
Ethylene	Ethylene reacts explosively with chlorine in sunlight or ultraviolet light.
	Haz. Chem. Data (1966).
	The reaction of chlorine and ethylene is explosive at room temperature over yellow mercuric oxide, mercurous oxide, or silver oxide.
	Mellor **2, Supp. 1:** 380 (1956).
Ethyleneimine	Ethyleneimine plus chlorine forms an explosive compound, 1-chloroethyleneimine.
	Ethyleneimine.
S-Ethyl Isothiourea	An explosion occurred during the chlorination
Sulfate	of S-ethyl isothiourea sulfate and formamidine thiolacetic acid•HCl. Formation of spontaneously explosive nitrogen

	trichloride was the suggested cause.
	J. Am. Chem. Soc. **63:** 3530-32 (1941).
Ethyl Phosphine	A mixture of ethyl phosphine and chlorine explodes.
	Von Schwartz, pp. 324, 325 (1918).
Fluorine	Reaction of chlorine and fluorine is accompanied by flames. In the presence of a spark, a violent explosion occurs.
	Mellor **2, Supp. 1:** 58 (1956).
Formamidine Thiolacetic Acid•HCl	See CHLORINE plus S-Ethyl Isothiourea Sulfate.
Germanium	See GERMANIUM plus Chlorine.
Glycerol	See CHLORINE plus Polypropylene.
Hydrazine	Hydrazine ignites in contact with chlorine.
	Mellor **8:** 313 (1946-1947).
Hydrocarbons	In a chemical process, chlorine inadvertently contacted hydrocarbon vapors at about 60 psig. An explosion ruptured the pipeline.
	MCA Case History **1035** (1964).
	Chlorine reacts vigorously with most hydrocarbons, causing ignition with some, e.g., turpentine.
	Mathieson Chlorine. Mellor **2, Supp. I:** 404.
	During treatment of naphtha with an aqueous caustic-hypochlorite solution to remove objectionable odors, an explosion occurred in the mixer. Just before the detonation, liquid chlorine had been added to strengthen the hypochlorite solution. The explosion is attributed to the highly exothermic liquid phase reaction of chlorine and saturated hydrocarbons.
	Chem. Eng. Progs. **58**(**6**): 71-74 (1962).
	Mellor **2, Supp. 1:** 380 (1956).
Hydrogen	A mixture of hydrogen and chlorine is exploded by almost any form of energy (heat, sunlight, sparks, etc.). Explosive

	range: 5% to 95%.
	Mathieson Chlorine.
Hydrogen Peroxide and Potassium Hydroxide	Red luminescence occurs during reaction of chlorine and hydrogen peroxide in strong potassium hydroxide solution.
	Mellor **2, Supp. 1:** 378 (1956).
Hydroxylamine	Hydroxylamine is spontaneously flammable in chlorine.
	Mellor **8:** 288 (1946-1947).
Iodine	The reaction of liquid chlorine and iodine is violent.
	Mellor **2, Supp. 1:** 378 (1956).
Iron	See IRON plus Chlorine.
Iron Carbide	Iron carbide burns in chlorine below 100¡C with incandescence and behaves similarly with bromine at about 100¡C.
	Mellor **5:** 858 (1946-1947).
Linseed Oil	See CHLORINE plus Polypropylene.
Lithium	See CESIUM plus Chlorine.
Lithium Acetylene Carbide Diammino	See LITHIUM ACETYLENE CARBIDE DIAMMINO plus Carbon Dioxide.
Lithium Carbide	See BROMINE plus Lithium Carbide.
Lithium Silicide	See FLUORINE plus Lithium Silicide.
Magnesium	See MAGNESIUM plus Chlorine.
Magnesium Phosphide	Magnesium phosphide burns brilliantly when heated in chlorine or bromine vapors.
	Mellor **8:** 842 (1946-1947).
Manganese	See MANGANESE plus Chlorine.
Manganese Ditritaphosphide	This phosphide ignites when gently heated in chlorine.

	Mellor **8:** 853 (1946-1947).
Mercuric Oxide	Chlorine reacts rapidly at room temperature with both mercuric oxide and silver oxide.
	Mellor **2, Supp. 1:** 381 (1956).
Mercuric Sulfide	Mercuric sulfide burns in chlorine with incandescence.
	Mellor **4:** 952 (1946-1947).
Mercury	See MERCURY plus Chlorine.
Mercury Tetratriphosphide	See MERCURY TETRATRIPHOSPHIDE plus Air.
Methane	The reaction of chlorine and methane is explosive at room temperature over yellow mercuric oxide.
	Mellor **2, Supp. 1:** 380 (1956).
Niobium (Columbium)	See NIOBIUM plus Chlorine.
	See NIOBIUM plus Fluorine.
Nitrogen Triiodide	See BROMINE plus Nitrogen Triiodide.
Oxomonosilane	The polymer of oxomonosilane ignites in air or chlorine.
	Mellor **6:** 234 (1946-1947).
Oxygen Difluoride	The reaction between chlorine and oxygen difluoride produces a reddish-brown solid that explodes at about minus 10¡ C.
	Mellor **2, Supp. 1:** 182 (1956).
	A mixture of chlorine and oxygen fluoride explodes on gentle warming. Puffs or more violent explosions occur if mixture is in copper tubing at 300¡ C.
	Mellor **2, Supp. 1:** 192 (1956).
Oxygen Difluoride and Copper	See CHLORINE plus Oxygen Difluoride.
Phosphine	See BROMINE plus Phosphine.
Phosphorus	See PHOSPHORUS plus Chlorine.
Phosphorus and	See PHOSPHORUS plus Chlorine and Heptane.

Heptane	
Phosphorus Isocyanate	The reaction of phosphorus isocyanate and chlorine is vigorous, forming a yellow oil.
	Mellor **8, Supp. 3:** 585 (1971).
Phosphorus Oxide	When phosphorus oxide is thrown into a jar of chlorine vapor, it ignites instantly. It reacts violently with liquid bromine and generally ignites.
	Mellor **8:** 897 (1946-1947).
Phosphorus Trioxide	See BROMINE plus Phosphorus Trioxide.
Polychlorinated	Liquid chlorine reacts exothermically with
Biphenyl	polychlorinated biphenyl heat transfer liquid.
	W. A. Statesir, *Chem. Eng. Progs.* **69** (4): 52-54 (1973).
Polydimethylsiloxane	See CHLORINE plus Polypropylene.
Polypropylene	Liquid chlorine reacts explosively with polypropylene, drawing wax, polydimethyl-siloxane, dibutyl phthalate, glycerol, and linseed oil.
	W. A. Statesir, *Chem. Eng. Progs.* **69** (4): 52-54 (1973).
Potassium	See POTASSIUM plus Chlorine.
Potassium Acetylene	Potassium acetylene carbide ignites spontaneously
Carbide	in cold chlorine, forming hydrogen chloride plus carbon.
	Mellor **5:** 849 (1946-1947) *Comp. Rend.* **127:** 916. *Comp. Rend.* **136:** 1220.
Potassium Hydride	Potassium hydride burns in fluorine or chlorine spontaneously.
	Mellor **2:** 483 (1946-1947).
Rubber	Rubber will burn in liquid chlorine. During chlorination of rubber, an explosion occurred causing pressure of over 1,100 psi.
	Chem. Eng. News **26:** 3369.
Rubidium	See CESIUM plus Chlorine.
Rubidium Acetylene	See BROMINE plus Rubidium Acetylene

Carbide	Carbide.
Silicon	See SILICON plus Chlorine.
Silicon Hydride	Silicon hydride ignites in a chlorine atmosphere. *Mellor* **6:** 219 (1946-1947).
Silver Oxide	See CHLORINE plus Mercuric Oxide.
Sodium	See SODIUM plus Chlorine.
Sodium Acetylene Carbide	See BROMINE plus Sodium Acetylene Carbide.
Sodium Carbide	See SODIUM CARBIDE plus Carbon Dioxide. This carbide burns in chlorine gas. *Mellor* **5:** 848 (1946-1947).
Sodium Hydride	Sodium hydride is spontaneously flammable in fluorine. With chlorine, moisture must also be present. *Mellor* **2:** 483 (1946-1947).
Stannous Fluoride	The reaction of chlorine and stannous fluoride occurs with flaming. *Mellor* **2, Supp. 1:** 382 (1956).
Stibine	See STIBINE plus Ammonia.
Strontium Phosphide	Mixtures of these materials ignite at about 30¡ C. *Mellor* **8:** 841 (1946-1947).
Sulfamic Acid	An explosion occurred when chlorine was being passed at room temperature into a reaction mixture which included sulfamic acid and water. It is suspected that nitrogen trichloride, a very sensitive explosive, was formed. *Short* (1966).
Tellurium	Warm chlorine attacks tellurium with incandescence. *Mellor* **11:** 26, 40 (1946-1947).
Tetramethyl Diarsine	Tetramethyl diarsine is spontaneously flammable in chlorine.

	ACS **15** (1923).
Thorium	See THORIUM plus Chlorine.
Tin	See TIN plus Chlorine.
Tungsten Dioxide	When tungsten dioxide is heated in chlorine the reaction occurs with incandescence.
	Mellor **11:** 851 (1946-1947).
Turpentine	See CHLORINE plus Hydrocarbons.
Uranium	Uranium ignites spontaneously if chlorine is heated to 150¡C.
	Mellor **12:** 31, 32 (1946-1947).
Uranium Dicarbide	See BROMINE plus Uranium Dicarbide.
Vanadium	Powdered vanadium explodes with chlorine, even at 0¡C.
	Mellor **Supp. II, Part I:** 715 (1956).
Zinc	See ZINC plus Chlorine.
Zirconium Dicarbide	See BROMINE plus Zirconium Dicarbide.

CHLORINE AZIDE N_3Cl

(self-reactive)	Chlorine azide is spontaneously explosive.
	Mellor **8:** 336 (1946-1947).
	Mellor **8, Supp. 2:** 50 (1967).
Butadiene-1, 3	Chlorine dioxide mixed with butadiene, ethane, ethylene, methane or propane always explodes spontaneously.
	J.K.K. Ip and P. Gray, *Comb. & Flame* **19:** 117-129 (1972).
Ethane	See CHLORINE DIOXIDE plus Butadiene.
Ethylene	See CHLORINE DIOXIDE plus Butadiene.
Methane	See CHLORINE DIOXIDE plus Butadiene.
Propane	See CHLORINE DIOXIDE plus Butadiene.

CHLORINE FLUOROXIDE ClOF

(self-reactive)	Chlorine fluoroxide is explosively unstable.
	Mellor **2, Supp. 1:** 182 (1956).

CHLORINE MONOFLUORIDE ClF

Organic Matter	See BROMINE MONOFLUORIDE plus Water.
Water	See BROMINE MONOFLUORIDE plus Water.

CHLORINE DIOXIDE ClO_2

(self-reactive)	With over 10% chlorine dioxide in air at pressures from 0.1 to 1.0 atmosphere, chlorine dioxide is violently explosive. Explosion may be initiated by almost any form of energy such as sunlight, heat, or sparks.
	Chem. Eng. News **29:** 5030 (1951).
Difluoroamine	The gas phase reaction of chlorine dioxide and difluoroamine is explosive.
	Lawless and Smith, p. 171 (1968).
Fluorine	See FLUORINE plus Chlorine Dioxide.
Mercury	See MERCURY plus Chlorine Dioxide.
Organic Matter	Organic material in contact with chlorine dioxide can be exploded by shock or sparks.
	R.F. Stedman, *Chem. Eng. News* **29:** 5030 (1951).
Phosphorus	See PHOSPHORUS plus Chlorine Dioxide.
Potassium Hydroxide	See POTASSIUM HYDROXIDE plus Chlorine Dioxide.
Sugar	See SULFUR plus Chlorine Dioxide.
Sulfur	See SULFUR plus Chlorine Dioxide.

CHLORINE FLUORIDE ClF

Tellurium	See TELLURIUM plus Chlorine Fluoride.

CHLORINE MONOXIDE Cl_2O

(self-reactive)	Chlorine monoxide is highly explosive if heated rapidly or overheated locally.
	Mellor **2, Supp. 1:** 517 (1956).
Ammonia	A mixture of chlorine monoxide and ammonia explodes.
	Mellor **2:** 241, 242 (1946-1947).
Antimony	See POTASSIUM plus Chlorine Monoxide.
Antimony Sulfide	See CHLORINE MONOXIDE plus Calcium Phosphide.
Arsenic	See POTASSIUM plus Chlorine Monoxide.
Barium Sulfide	See CHLORINE MONOXIDE plus Calcium Phosphide.
Calcium Phosphide	Calcium phosphide causes chlorine monoxide to explode; chlorine monoxide also causes explosions with sulfides of barium, tin, antimony and mercury.
	Mellor **2:** 242 (1946-1947).
Carbon	See CHLORINE MONOXIDE plus Charcoal.
Carbon Disulfide	Chlorine monoxide explodes in contact with carbon disulfide vapor.
	Mellor **6:** 110 (1946-1947).
Charcoal	An immediate explosion occurs when charcoal is added to chlorine monoxide.
	Mellor **5:** 822-30 (1946-1947).
Hydrogen Sulfide	A mixture of chlorine monoxide and hydrogen sulfide explodes.
	Mellor **2:** 241-42 (1946-1947).
Mercury Sulfide	See CHLORINE MONOXIDE plus Calcium Phosphide.
Metal Sulfides	See CHLORINE MONOXIDE plus Calcium Phosphide.
Nitric Oxide	A mixture of nitric oxide and chlorine monoxide can be explosive.
	Ann. Chim. et Phys. (2) **57:** 225.

Organic Matter	Chlorine monoxide often explodes violently in contact with organic compounds.
	Mellor **2, Supp. 1:** 520 (1956).
	See POTASSIUM plus Chlorine Monoxide.
Phosphine	Chlorine monoxide explodes on contact with phosphine.
	Taylor (1831).
Phosphorus	See CHLORINE MONOXIDE plus Calcium Phosphide.
Sulfur	See POTASSIUM plus Chlorine Monoxide.
Tin Sulfides	See CHLORINE MONOXIDE plus Calcium Phosphide.
Turpentine	See POTASSIUM plus Chlorine Monoxide.

CHLORINE TRIFLUORIDE ClF_3

Acetic Acid	The reaction between chlorine trifluoride and acetic acid is very violent, sometimes explosive.
	Mellor **2, Supp. 1:** 155 (1956).
Aluminum	See ALUMINUM plus Chlorine Trifluoride.
Aluminum Oxide	Chlorine trifluoride reacts violently, producing flame, with aluminum oxide, calcium oxide, chromium oxide, lead dioxide, magnesium oxide, manganese dioxide, molybdenum trioxide, tantalum pentoxide, tungsten trioxide, or vanadium pentoxide.
	Mellor **2, Supp. 1:** 157 (1956).
	See also CHLORINE TRIFLUORIDE plus Elements.
Ammonia	Chlorine trifluoride causes an explosive reaction with ammonia, carbon monoxide, hydrogen sulfide, sulfur dioxide, or hydrogen.
	Mellor **2, Supp. 1:** 157 (1956).
Antimony	See ANTIMONY plus Chlorine Trifluoride.
Arsenic	See ANTIMONY plus Chlorine Trifluoride.
Arsenic Trioxide	Chlorine trifluoride produces a violent reaction without flame in presence of arsenic trioxide, bismuth trioxide,

	lanthanum oxide, phosphorus pentoxide, or stannic oxide.
	Mellor **2, Supp. 1:** 157 (1956).
	See also CHLORINE TRIFLUORIDE plus Elements.
Benzene	The reaction between chlorine trifluoride and benzene is very violent, sometimes explosive.
	Mellor **2, Supp. 1:** 155 (1956).
Bismuth Trioxide	See CHLORINE TRIFLUORIDE plus Arsenic Trioxide.
Calcium	See CALCIUM plus Chlorine Trifluoride.
Calcium Oxide	See CHLORINE TRIFLUORIDE plus Aluminum Oxide.
Carbon Monoxide	See CHLORINE TRIFLUORIDE plus Ammonia.
Charcoal	Chlorine trifluoride causes charcoal, glass wool (rapidly etched with traces of moisture), or graphite to burst into flame.
	Mellor **2, Supp. 1:** 157 (1956).
Chlorotrifluoroethylene Polymer (Kel-F Oil) and Water	While chlorine trifluoride was being passed through Kel-F Oil for disposal the inadvertent introduction of moisture set up the exothermic water-plus-chlorine trifluoride reaction. The heat evolved initiated a violent reaction with the Kel-F Oil.
	Chem. Eng. News **43** (20): 41 (1965).
Chromic Anhydride	Chlorine trifluoride and chromic anhydride react violently with evolution of brown fumes.
	Mellor **2, Supp. 1:** 157 (1956).
	Mellor **11:** 230 (1946-1947).
Chromic Oxide	Reaction between chlorine trifluoride and chromic oxide is accompanied by incandescence.
	Mellor **11:** 181 (1946-1947).
Chromium Oxide	See also CHLORINE TRIFLUORIDE plus Aluminum Oxide.
Copper	See ALUMINUM plus Chlorine Trifluoride.
Diethyl Ether	The reaction between chlorine and diethyl ether is very

	violent, sometimes explosive.
	Mellor **2, Supp. 1:** 155 (1956).
Elements	Most chemical elements are attacked explosively by chlorine trifluoride. Most oxides behave the same way. Glass wool catches fire in the vapor. One drop of the liquid sets fire to paper, cloth, or wood. The reaction is violent with water or ice.
	Sidgwick, p. 1156 (1950). *Matheson Gas Data,* p. 108 (1961).
Glass	Glass wool catches fire readily in the vapor. Chlorine trifluoride flowing in glass tubing at excessive rates or pressures can cause the glass to burn.
	Sidgwick, p. 1156 (1950). *Yunker* (1966).
	See also CHLORINE TRIFLUORIDE plus Charcoal.
Graphite	See CHLORINE TRIFLUORIDE plus Charcoal.
Hydrogen	See CHLORINE TRIFLUORIDE plus Ammonia.
Hydrogen Sulfide	See CHLORINE TRIFLUORIDE plus Ammonia.
Iodine	See CHLORINE TRIFLUORIDE plus Mercuric Iodide.
Iridium	See IRIDIUM plus Chlorine Trifluoride.
Iron	See IRON plus Chlorine Trifluoride.
Lanthanum Oxide	See CHLORINE TRIFLUORIDE plus Arsenic Trioxide.
Lead	See ALUMINUM plus Chlorine Trifluoride.
Lead Dioxide	See CHLORINE TRIFLUORIDE plus Aluminum Oxide.
Magnesium	See ALUMINUM plus Chlorine Trifluoride.
Magnesium Oxide	See CHLORINE TRIFLUORIDE plus Aluminum Oxide.
Manganese Dioxide	See MANGANESE DIOXIDE plus Chlorine Trifluoride.
	See also CHLORINE TRIFLUORIDE plus Aluminum Oxide.
Mercuric Iodide	Combination of chlorine trifluoride and mercuric iodide, tungsten carbide, or iodine results in a reaction with flame.
	Mellor **2, Supp. 1:** 157 (1956).

Molybdenum	See MOLYBDENUM plus Chlorine Trifluoride.
Molybdenum Trioxide	See MOLYBDENUM TRIOXIDE plus Chlorine Trifluoride.
	See also CHLORINE TRIFLUORIDE plus Aluminum Oxide.
Nitric Acid (Fuming)	Combination of chlorine trifluoride and fuming nitric acid, potassium carbonate, potassium iodide, silver nitrate, 10% sodium hydroxide or sulfuric acid results in a violent reaction.
	Mellor **2, Supp. 1:** 157 (1956).
Nitroaromatic Compounds	See NITROAROMATIC COMPOUNDS plus Chlorine Trifluoride.
Organic Matter	Chlorine trifluoride is compatible with other oxidizers such as OF_2 and ClO_3F, but reacts violently with organics. See also CHLORINE TRIFLUORIDE plus Elements.
	Lawless and Smith, p. 114 (1968).
	Mellor **2, Supp. 1:** 155 (1956).
	See also BROMINE MONOFLUORIDE plus Water.
Osmium	See ANTIMONY plus Chlorine Trifluoride.
Oxides	See CHLORINE TRIFLUORIDE plus Elements.
Phosphorus	See ANTIMONY plus Chlorine Trifluoride.
Phosphorus Pentoxide	See CHLORINE TRIFLUORIDE plus Arsenic Trioxide.
Potassium	See ANTIMONY plus Chlorine Trifluoride.
Potassium Carbonate	See CHLORINE TRIFLUORIDE plus Nitric Acid.
Potassium Iodide	See CHLORINE TRIFLUORIDE plus Nitric Acid.
Rhodium	See ANTIMONY plus Chlorine Trifluoride.
Rubber	When chlorine trifluoride is in contact with rubber a violent reaction occurs.
	Mellor **2, Supp. 1:** 156 (1956).
Selenium	See ANTIMONY plus Chlorine Trifluoride.

Silicon	See ANTIMONY plus Chlorine Trifluoride.
Silver	See ALUMINUM plus Chlorine Trifluoride.
Silver Nitrate	See CHLORINE TRIFLUORIDE plus Nitric Acid.
Sodium	See CALCIUM plus Chlorine Trifluoride.
Sodium Hydroxide	See CHLORINE TRIFLUORIDE plus Nitric Acid.
Stannic Oxide	See CHLORINE TRIFLUORIDE plus Arsenic Trioxide.
Sulfur	See ANTIMONY plus Chlorine Trifluoride.
Sulfur Dioxide	See CHLORINE TRIFLUORIDE plus Ammonia.
Sulfuric Acid	See CHLORINE TRIFLUORIDE plus Nitric Acid.
Tantalum Pentoxide	See CHLORINE TRIFLUORIDE plus Aluminum Oxide.
Tellurium	See ANTIMONY plus Chlorine Trifluoride.
Tin	See ALUMINUM plus Chlorine Trifluoride.
Tungsten	See ANTIMONY plus Chlorine Trifluoride.
Tungsten Carbide	See CHLORINE TRIFLUORIDE plus Mercuric Iodide.
Tungsten Trioxide	See TUNGSTEN TRIOXIDE plus Chlorine Trifluoride.
	See also CHLORINE TRIFLUORIDE plus Aluminum Oxide.
Vanadium Pentoxide	See CHLORINE TRIFLUORIDE plus Aluminum Oxide.
Water	See CHLORINE TRIFLUORIDE plus Elements.
	See also BROMINE MONOFLUORIDE plus Water.
Zinc	See ALUMINUM plus Chlorine Trifluoride.

CHLORINE TRIOXIDE ClO_3

(self-reactive)	Explosions occurred during preparation of chlorine trioxide.
	Mellor **2, Supp. 1:** 540 (1956).
Ethyl Alcohol	No really safe conditions exist under which ethyl alcohol and chlorine oxides can be handled.

	Mellor **2, Supp. 1:** 540 (1956).
Organic Matter	Chlorine trioxide reacts violently, even explosively, with stopcock grease, wood, most forms of organic matter.
	Mellor **2, Supp. 1:** 540 (1956).
Phosphorus	See PHOSPHORUS plus Chlorine Trioxide.
Phosphorus Pentachloride	When chlorine trioxide is passed over phosphorus pentachloride, there is often a vigorous explosion, explosive chlorine monoxide being formed.
	Bull. Acad. Belg. (2) **38:** 503 (1814).
Water	Chlorine trioxide reacts vigorously and may explode with water.
	Mellor **2, Supp. 1:** 540 (1956).

CHLORITES

(See also specific chlorites)

Ammonia	This reaction produces ammonium chlorite, which is a shock-sensitive compound.
	Federoff **3:** C-254 (1966).
Organic Matter	See CHLORITES plus Metals.
Metals	Finely divided metallic or organic substances, if mixed with chlorites, are highly flammable and may be ignited by friction.
	Lab. Govt. Chemist (1965).

CHLOROACETALDEHYDE OXIME $ClCH_2CH{=}NOH$

(self-reactive)	Separation of chloroacetaldehyde oxime from ether by distillation must not be carried out too far or a violent explosion will occur.
	MCA Guide for Safety, Appendix 3 (1972).

CHLOROACETONE $ClCH_2COCH_3$

(self-reactive)	Chloroacetone had turned black during storage for two years on a shelf in dull diffused light. A few days after the bottle of chloroacetone was moved, it exploded. The chloroacetone had polymerized to a black rubber-like substance. *Ind. & Eng. Chem. News* **9:** 184 (1931).

CHLOROACETYLENE HC≡CCl

(self-reactive)	See POTASSIUM HYDROXIDE plus 1,2-Dichloroethylene.
Air	See POTASSIUM HYDROXIDE plus 1,2-Dichloroethylene.

m-CHLOROANILINE DIAZONIUM CHLORIDE $NH_2 \cdot C_6H_4N(\equiv N)Cl$

Sodium Bisulfide	See SODIUM SULFIDE plus Diazonium Salts and Diazonium Chloride Salts.
Sodium Polysulfide	See SODIUM SULFIDE plus Diazonium Salts and Diazonium Chloride Salts.
Sodium Sulfide	See SODIUM SULFIDE plus Diazonium Salts and Diazonium Chloride Salts.

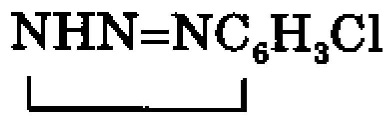
CHLOROAZODIN $ClN{=}C(NH_2)N{=}NC(NH_2)NCl$

(self-reactive)	Chloroazodin decomposes explosively at about 155¡C. The decomposition is accelerated by contact with metals. *Merck Index,* p. 240 (1968).

CHLOROBENZENE C_6H_5Cl

Dimethyl Sulfoxide	See DIMETHYL SULFOXIDE plus Acyl Halides.
Silver Perchlorate	See SILVER PERCHLORATE plus Acetic Acid.

5-CHLOROBENZOTRIAZOLE



(self-reactive)	5-Chlorobenzotriazole spontaneously burst into flame while being packaged.
	H. S. Hopps, *Chem. Eng. News* **49** (30): 3 (1971).
	J. Chem. Eng. Data **17:** 108 and 109 (1972).

3-CHLOROCYCLOPENTENE (-$CH{=}CHCHClCH_2CH_2$-)

(self-reactive)	Thirty-five grams of 3-chlorocyclopentene exploded one day after it was made.
	Merck Safety Report (April 1962).

CHLORODIBORANE $ClBH(H_2)BH_2$

Air	This compound is spontaneously flammable in air.
	Mellor **5:** 37 (1946-1947). *Douda* (1966).

CHLORODIETHYLALUMINUM $(C_2H_5)_2AlCl$

Benzene and Allyl Chloride	See ALLYL CHLORIDE plus Benzene and Ethyl Aluminum Dichloride.
Toluene and Allyl Chloride	See ALLYL CHLORIDE plus Benzene and Ethyl Aluminum Dichloride.
Water	Diethyl aluminum chloride reacts violently with water.
	Rose (1961).

CHLORODIETHYLBISMUTHINE $(C_2H_5)_2BiCl$

Air	Diethyl bismuth chloride is spontaneously flammable in air.
	Coates, p. 161 (1956).

CHLORODIETHYLBORANE $(C_2H_5)_2BCl$

Air	Diethyl boron chloride is spontaneously flammable in air.
	Buls, *Bimonthly Rept. 5*, p. 3 (1953).

2-CHLORO-1, 1-DIETHOXYETHANE $(C_2H_5O)_2CHCH_2Cl$

Sodium Amide	See SODIUM AMIDE plus 1,1-Diethoxy-2-Chloroethane.

CHLORODIISOBUTYLALUMINUM $AlCl(C_4H_9)_2$

Air	Diisobutyl aluminum chloride ignites spontaneously in air.
	J. E. Knap, R. E. Leach et al., *Ind. Eng. Chem.* **49** (5): 874-879 (1957).

CHLORO (DIMETHYLAMINO) DIBORANE $(CH_3)_2NB_2H_4Cl$

Air	Dimethylamino chlorodiborane is spontaneously flammable in air.
	A. B. Burg and C. L. Randolph, Jr., *J. Am. Chem. Soc.* **71:** 3451-3455 (1949).

1-CHLORO-2, 4-DINITROBENZENE $(O_2N)_2C_6H_3Cl$

(self-reactive)	An explosion may occur when the solvent symmetrical tetrachlorethane is almost removed in the chlorinolysis of 2, 4-dinitrophenyl disulfide.
	MCA Guide for Safety, Appendix 3 (1972).
	2, 4-Dinitrochlorobenzene has been known to detonate at

	about 300¡F. It can be detonated by shock or heat under confinement that will permit high pressure build-up.
	Haz. Chem. Data, p. 85 (1966).
Hydrazine Hydrate	See HYDRAZINE HYDRATE plus 2, 4-Dinitrochlorobenzene.
	See also 2, 4-Dinitrochlorobenzene.

4-CHLORO-3,6-DINITROPHENYLDIAZONIUM-2-OXIDE

$C_6H_2(NO_2)_2ClNNO$

(self-reactive)	See 4-CHLORO-2-NITROANILINE plus Nitric Acid.

x-CHLORO-2, 4-DINITROTOLUENE $C_6H_3(NO_2)_2CH_2Cl$

(self-reactive)	2,4-Dinitrochlorotoluene has been known to detonate at about 300¡F. It can be exploded by shock or heat under confinement that will permit high pressure build-up.
	Van Dolah (1966).

CHLORODIPROPYLBORANE $(C_3H_7)_2BCl$

Air	Dipropylchloroborine is spontaneously flammable in air.
	Douda (1966).

2-CHLOROETHANOL $ClCH_2CH_2OH$

Chlorosulfonic Acid	Mixing ethylene chlorohydrin and chlorosulfonic acid in a closed container caused the temperature and pressure to increase.
	Flynn and Rossow (1970). See Note under complete reference.
Ethylene Diamine	Mixing ethylene chlorohydrin and ethylene diamine in a closed container caused the temperature and pressure to increase.
	Flynn and Rossow (1970). See Note under complete

	reference.
Sodium Hydroxide	See SODIUM HYDROXIDE plus Chlorohydrin.

2-CHLOROETHYLENIMINE CHCl=C=NH

(self-reactive)	A distilled 50-gram quantity, after sitting in an amber bottle for three months, exploded suddenly. A black residue indicated it may have polymerized.
	Chem. Eng. News **42** (8): 41 (1964); *Chem. Eng. News* **36** (43): 52 (1958).

N-CHLOROETHYLENIMINE

(self-reactive)	*MCA Guide for Safety*, Appendix 3 (1972).

CHLOROFLUOROHYDROCARBONS

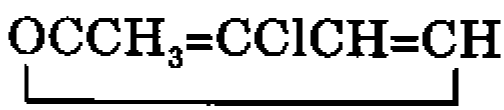
Aluminum	See ALUMINUM plus Chlorofluorohydrocarbons.

CHLOROFORM Cl_3CH

Acetone	See ACETONE plus Chloroform.
Aluminum	See ALUMINUM plus Chlorinated Hydrocarbons and ALUMINUM plus Chloroform.
Disilane	See DISILANE plus Carbon Tetrachloride.
Lithium	See LITHIUM plus Chloroform.
Magnesium	See MAGNESIUM plus Chloroform.
Nitrogen Tetroxide	See NITROGEN TETROXIDE plus 1,2-Dichloroethane.
Perchloric Acid and	See PHOSPHORUS PENTOXIDE plus Perchloric

Phosphorus Pentoxide	Acid and Chloroform.
Potassium	See POTASSIUM plus Chloroform.
Potassium Hydroxide and Methyl Alcohol	See SODIUM HYDROXIDE plus Chloroform and Methyl Alcohol.
Potassium Tert.-Butoxide	See ACETONE plus Potassium Tert.-Butoxide.
Sodium	See SODIUM plus Chloroform.
Sodium Hydroxide and Methyl Alcohol	See SODIUM HYDROXIDE plus Chloroform and Methyl Alcohol.
Sodium Methylate	See SODIUM METHYLATE plus Chloroform.
Sodium-Potassium Alloy	See SODIUM-POTASSIUM ALLOY plus Carbon Tetrachloride.
	See LITHIUM plus Chloroform.

3-CHLORO-2-METHYLFURAN



(self-reactive)	A small sample (20 milliliters) had been made, distilled and allowed to stand over the weekend. During the weekend it exploded. *MCA Guide for Safety,* Appendix 3 (1972).
Lithium Aluminum Hydride and Ethyl Acetate	A mixture of chlorinated organic compounds consisting principally of 3-CHLORO-2-METHYLFURAN was subjected to reductive dechlorination with lithium aluminum hydride, after which ethyl acetate was added in small increments to decompose excess lithium aluminum hydride. After a few drops had been added, a violent explosion occurred. *Chem. & Ind.* **14:** 432 (1957).

4-CHLORO-2-NITROANILINE $NO_2(Cl)C_6H_3NH_2$

Nitric Acid	In a large scale-up of the method for preparing 4-chloro-2,6-dinitroaniline by reacting nitric acid with 4-chloro-2-nitroaniline, an unexpected strong evolution of heat was experienced. The exotherm was found due to the simultaneous formation of two explosive products — the isomer 2-chloro-4,6-dinitroaniline and also 4-chloro-3,6-dinitrophenyldiazonium-2-oxide. The latter is very shock sensitive. *MCA Case History* **1489** (1968).

CHLORONITROTOLUENES

Sodium Hydroxide	The feed stream into a tank of mixed chloronitrotoluenes became inadvertently contaminated with caustic. The runaway reaction within the tank ripped the tank open in spite of a 10-inch relief vent. *MCA Case History* **907** (1963).

CHLOROPENTAMMINE COBALT PERCHLORATE

(See COBALTOUS-PENTAMMINE CHLORO-PERCHLORATE)

p-CHLOROPHENYL ISOCYANATE ClC_6H_4NCO

(self-reactive)	A violent explosion occurred in a laboratory during vacuum distillation of p-chlorophenyl isocyanate that had been prepared by the Curtius reaction of p-chlorobenzoylazide. *Chem. & Ind.* **38:** 1625 (1965).

CHLOROPICRIN Cl_3CNO_2

(self-reactive)	Tank car volumes of this material may detonate under certain conditions. There is a critical volume above which sufficient shock may cause detonation.

	Chem. Eng. News **50** (38): 13 (1972).
Propargyl Bromide	See PROPARGYL BROMIDE plus Chloropicrin.

3-CHLORO-1-PROPYNE CH≡CCH_2Cl

(self-reactive)	See PROPARGYL BROMIDE. Liquid propargyl chloride is much less susceptible to this type ignition. D. R. Forshey et al., *Fire Tech.* **5** (2):100-111 (1969).

CHLOROSILANE $ClSiH_3$

Ammonia	With insufficient ammonia, chlorosilane forms trisilylammonia which is spontaneously flammable in air. *Mellor* **8:** 262 (1946-1947).

CHLOROSILANES ClxSiHy

Air	The chlorosilicon hydrides are spontaneously flammable in air. *Ellern*, p. 22 (1968).

CHLOROSILICON HYDRIDES

(See CHLOROSILANES)

CHLOROSULFONIC ACID

(See CHLOROSULFURIC ACID)

CHLOROSULFURIC ACID $ClSO_2OH$

Acetic Acid	See ACETIC ACID plus Chlorosulfonic Acid.
Acetic Anhydride	See ACETIC ANHYDRIDE plus Chlorosulfonic Acid.
Acetonitrile	See ACETONITRILE plus Chlorosulfonic Acid.

Acrolein	See ACROLEIN plus Chlorosulfonic Acid.
Acrylic Acid	See ACRYLIC ACID plus Chlorosulfonic Acid.
Acrylonitrile	See ACRYLONITRILE plus Chlorosulfonic Acid.
Allyl Alcohol	See ALLYL ALCOHOL plus Chlorosulfonic Acid.
Allyl Chloride	See ALLYL CHLORIDE plus Chlorosulfonic Acid.
2-Aminoethanol	See 2-AMINOETHANOL plus Chlorosulfonic Acid.
Ammonium Hydroxide	Mixing chlorosulfonic acid and 28% ammonia in a closed container caused the temperature and pressure to increase.
	Flynn and Rossow (1970). See Note under complete reference.
Aniline	See ANILINE plus Chlorosulfonic Acid.
n-Butyraldehyde	See n-Butyraldehyde plus Chlorosulfonic Acid.
Creosote Oil	Mixing chlorosulfonic acid and creosote oil in a closed container caused the temperature and pressure to increase.
	Flynn and Rossow (1970). See Note under complete reference.
Cresol	See CRESOL plus Chlorosulfonic Acid.
Cumene	See CUMENE plus Chlorosulfonic Acid.
Dichloroethyl Ether	See DICHLOROETHYL ETHER plus Chlorosulfonic Acid.
Diethylene Glycol Monomethyl Ether	See DIETHYLENE GLYCOL MONOMETHYL ETHER plus Chlorosulfonic Acid.
Diisobutylene	See DIISOBUTYLENE plus Chlorosulfonic Acid.
Diisopropyl Ether	See DIISOPROPYL ETHER plus Chlorosulfonic Acid.
Epichlorohydrin	See EPICHLOROHYDRIN plus Chlorosulfonic Acid.
Ethyl Acetate	See ETHYL ACETATE plus Chlorosulfonic Acid.
Ethyl Acrylate	See ETHYL ACRYLATE plus Chlorosulfonic Acid.
Ethylene Chlorohydrin	See ETHYLENE CHLOROHYDRIN plus Chlorosulfonic Acid.
Ethylene Cyanohydrin	See ETHYLENE CYANOHYDRIN plus Chlorosulfonic

	Acid.
Ethylene Diamine	See ETHYLENE DIAMINE plus Chlorosulfonic Acid.
Ethylene Glycol	See ETHYLENE GLYCOL plus Chlorosulfonic Acid.
Ethylene Glycol Monoethyl Ether Acetate	See ETHYLENE GLYCOL MONOETHYL ETHER ACETATE plus Chlorosulfonic Acid.
Ethyleneimine	See ETHYLENEIMINE plus Chlorosulfonic Acid.
Glyoxal	See GLYOXAL plus Chlorosulfonic acid.
Hydrochloric Acid	Mixing chlorosulfonic acid and 36% hydrochloric acid in a closed container caused the temperature and pressure to increase. *Flynn and Rossow* (1970). See Note under complete reference.
Hydrofluoric Acid	Mixing chlorosulfonic acid and 48.7% hydrofluoric acid in a closed container caused the temperature and pressure to increase. *Flynn and Rossow* (1970). See Note under complete reference.
Hydrogen Peroxide	Permonosulfonic acid was being prepared by reacting chlorosulfonic acid and 90% hydrogen peroxide. A sample was stored overnight at 0¡ C, then removed to a test tube rack. In ten minutes it exploded. *Chem. Eng. News* **33:** 3336 (1955). See also PERMONOSULFURIC ACID plus Acetone.
Isoprene	See ISOPRENE plus Chlorosulfonic Acid.
Mesityl Oxide	See MESITYL OXIDE plus Chlorosulfonic acid.
Metallic Powders	See CHLOROSULFONIC ACID plus Organic Matter.
Methyl Ethyl Ketone	See METHYL ETHYL KETONE plus Chlorosulfonic Acid.
Nitric Acid	Mixing chlorosulfonic acid and 70% nitric acid in a closed container caused the temperature and pressure to increase. *Flynn and Rossow* (1970). See Note under complete

	reference.
2-Nitropropane	Mixing chlorosulfonic acid and 2-nitropropane in a closed container caused the temperature pressure to increase.
	Flynn and Rossow (1970). See Note under complete reference.
Organic Matter	This material is dangerous in contact with combustible materials, nitrates, chlorates, metallic powders, carbides, picrates and fulminates. It develops great heat in contact with water.
	Chem. Safety Data Sheet **SD-33** (1949).
Phosphorus	See PHOSPHORUS plus Chlorosulfonic Acid.
Propiolactone (beta-)	See PROPIOLACTONE (beta-) plus Chlorosulfonic Acid.
Propylene Oxide	See PROPYLENE OXIDE plus Chlorosulfonic Acid.
Pyridine	See PYRIDINE plus Chlorosulfonic Acid.
Sodium Hydroxide	See SODIUM HYDROXIDE plus Chlorosulfonic Acid.
Styrene Monomer	See STYRENE MONOMER plus Chlorosulfonic Acid.
Sulfolane	See SULFOLANE plus Chlorosulfonic Acid.
Sulfuric Acid	Mixing chlorosulfonic acid and 96% sulfuric acid in a closed container caused the temperature and pressure to increase.
	Flynn and Rossow (1970). See Note under complete reference.
Vinyl Acetate	See VINYL ACETATE plus Chlorosulfonic Acid.
Vinylidene Chloride	See VINYLIDENE CHLORIDE plus Chlorosulfonic Acid.
Water	See CHLOROSULFONIC ACID plus Organic Matter.

CHLOROTHION $(CH_3O)_2P(S)OC_6H_3ClNO_2$

(self-reactive)	When a sample was heated in a small test tube it decomposed and in a few minutes the residue exploded.
	J.B. McPherson and G.A. Johnson, *Agri. Food Chem.* **4** (1): 42 (1956).

4-CHLORO-o-TOLUIDINE DIAZONIUM CHLORIDE SALT

$NH_2C_6H_3(Cl)CH_2N(\equiv N)Cl$

Sodium Bisulfide	See SODIUM SULFIDE plus Diazonium Salts and Diazonium Chloride Salts.
Sodium Polysulfide	See SODIUM SULFIDE plus Diazonium Salts and Diazonium Chloride Salts.
Sodium Sulfide	See SODIUM SULFIDE plus Diazonium Salts and Diazonium Chloride Salts.

CHLOROTRIFLUOROETHYLENE $ClFC{=}CF_2$

Bromine and Oxygen	Addition of bromine to a mixture of chlorotrifluoroethylene and oxygen causes an explosion. One of the products of the reaction is chlorotrifluoroethylene peroxide, which explodes when heated.
	R.N. Haszeldine and F. Nyman, *J. Chem. Soc.* **1959:** 1084-1090 (1959).
Chlorine Trifluoride	See CHLORINE TRIFLUORIDE plus Chlorotrifluoroethylene
and Water	Polymer and Water.

CHLOROTRIFLUOROETHYLENE PEROXIDE CF_2ClCOF

(self-reactive)	Chlorotrifluoroethylene peroxide explodes when heated.
	R.N. Haszeldine and F. Nyman, *J. Chem. Soc.* **1959:** 1084-90 (1959).

CHLOROTRIFLUOROMETHANE $CClF_3$

Aluminum	See ALUMINUM plus Dichlorodifluoromethane.

CHLOROTRIMETHYLSILANE $(CH_3)_3SiCl$

Water	Trimethyl chlorosilane reacts violently with water yielding heat and white acid fumes. *Title* 46 (1970).

CHROMATES

Hydrazine	Hydrazine is decomposed explosively by chromates and chromic anhydride. *Mellor* **11:** 234 (1946-1947).

CHROMIC ACID

(See CHROMIC ANHYDRIDE)

CHROMIC ANHYDRIDE CrO_3

(CHROMIC ACID; CHROMIUM VI OXIDE;

CHROMIUM TRIOXIDE)

Acetic Acid	Acetic acid or acetic anhydride can explode with chromic acid if not kept cold. *Von Schwartz*, p. 321 (1918).
Acetic Anhydride	During the preparation of chromyl acetate by the direct reaction of chromic anhydride on acetic anhydride without the use of diluting solvents, a violent explosion occurred. J.G. Dawber, *Chem. & Ind.* **23:** 973 (Part I, 1964). See also CHROMIC ANHYDRIDE plus Acetic Acid.
Acetic Anhydride and Acetic Acid	Acetic anhydride was gradually being titrated into a mixture of chromic anhydride and acetic acid in a 20-gallon, glass-lined tank. After 1 1/2 hours of this procedure, the contents of the reactor exploded. *Doyle* (1966).
Acetone	An attempt to purify acetone by refluxing with chromic anhydride led to an explosion and fire when the acetone

	was first brought into contact with the chromic anhydride.
	Robert Delhez, *Chem. & Ind.:* 931 (Sept. 8, 1956).
Aluminum	See ALUMINUM plus Chromic Anhydride.
Ammonia	Ammonia gas decomposes the dry trioxide with incandescence at ordinary temperatures.
	Mellor **11:** 161 (1946-1947).
	Mellor **11:** 233 (1946-1947).
Anthracene	Anthracene will burst into flame on contact with chromic acid.
	Douglas and Thompson (1949).
Arsenic	See ARSENIC plus Chromium Trioxide.
Benzene	Benzene ignites in contact with powdered chromic anhydride.
	Mellor **11:** 235 (1946-1947).
Camphor	See CHROMIC ANHYDRIDE plus Naphthalene.
Chlorine Trifluoride	See CHLORINE TRIFLUORIDE plus Chromic Anhydride.
Chromous Sulfide	Ignition occurs when chromium trioxide comes in contact with a small proportion of chromium sulfide.
	Mellor **11:** 430 (1946-1947).
Diethyl Ether	These compounds react violently at room temperature.
	Mellor **11:** 235 (1946-1947).
Dimethyl Formamide	A violent reaction occurred when chromic anhydride was added rapidly or in large lumps to dimethyl formamide.
	Chem. Eng. News **48** (28): 4 (July 6, 1970).
Ethyl Alcohol	Chromic anhydride ignites ethyl alcohol.
	Durrant, p. 990 (1962).
Glycerol	See CHROMIC ANHYDRIDE plus Naphthalene.
Hydrocarbons	Chromic anhydride ignites many hydrocarbons.
	Campbell and Young, *Science* **104:** 353 (1946).

Hydrogen Sulfide	When hydrogen sulfide is passed over heated chromium trioxide, decomposition occurs with incandescence.
	Mellor **11:** 232 (1946-1947).
	See also CHROMIC ANHYDRIDE plus Naphthalene.
Methyl Alcohol	A laboratory preparation of hexa-aquochromic sulfate required the reduction of chromic anhydride by methyl alcohol. When the alcohol was contacted by the anhydride, an explosion and fire resulted.
	Delhez (1967).
Naphthalene	Naphthalene, camphor, glycerol, or turpentine will react violently with chromic anhydride.
	Haz. Chem. Data, p. 68 (1967).
Organic Matter	A container of 50 kilograms of chromic anhydride exploded when laid on the ground. The container may have been contaminated with an oxidizable substance.
	Chem. Abst. **31:** 4010 (1937).
Phosphorus	See PHOSPHORUS plus Chromium Trioxide.
Potassium	See POTASSIUM plus Chromium Trioxide.
Potassium Ferricyanide	While these two compounds were being mixed, an explosion occurred when the dust was ignited by a spark.
	Mich. Occ. Health **7:** No. 2, p. 2 (Winter 1962).
Pyridine	During the preparation of a chromium trioxide-pyridine complex, the proportion of the trioxide was increased. Since the trioxide dissolves in the pyridine by swelling, then rapidly dissolving with evolution of heat, the excessive amount of chromium trioxide produced overheating, which resulted in an explosion and fire.
	MCA Case History **1284** (1967).
Selenium	See SELENIUM plus Chromium Trioxide.
Sodium	See SODIUM plus Chromium Trioxide.
Sodium Amide	See SODIUM AMIDE plus Chromic Anhydride.
Sulfur	See SULFUR plus Chromic Anhydride.

Turpentine	See CHROMIC ANHYDRIDE plus Naphthalene.

CHROMIC-HEXAMMINE NITRATE $[Cr(NH_3)_6](NO_3)_3$

(self-reactive)	Hexammine chromium nitrate explodes at 265¡C and is impact sensitive. W.R. Tomlinson, Jr., and L.F. Audrieth, *J. Chem. Edu.* **27:** 606-609 (1950).

CHROMIC OXIDE Cr_2O_3

(See CHROMIUM OXIDE)

CHROMIUM Cr

Ammonium Nitrate	See AMMONIUM NITRATE plus Metals (powdered).
Hydrogen Peroxide	See IRON plus Hydrogen Peroxide.
Lithium	See LITHIUM plus Vanadium.
Nitric Oxide	Pyrophoric chromium unites with nitric oxide with incandescence. *Mellor* **11:** 162 (1946-1947).
Potassium Chlorate	Chromium is attacked vigorously by fused potassium chlorate, producing vivid incandescence. *Mellor* **11:** 163 (1946-1947).
Sulfur Dioxide	Pyrophoric chromium unites with sulfur dioxide with incandescence. *Mellor* **11:** 161 (1946-1947).

CHROMIUM-AMMINE NITRATES

(self-reactive)	Chromium-ammine nitrates may be impact-sensitive: $Cr(NH_3)_5NO_2(NO_3)_2$ detonates when heated. *Mellor* **11:** 477 (1946-1947).

CHROMIUM-AMMINE PERCHLORATES

(self-reactive)	Chromium-ammine perchlorates may be impact-sensitive.
	Mellor **11:** 477 (1946-1947).

CHROMIUM OXIDE Cr_2O_3

(CHROMIC OXIDE; CHROMIUM iii OXIDE;
CHROMIUM SESQUIOXIDE)

Chlorine Trifluoride	See CHLORINE TRIFLUORIDE plus Chromic Oxide.
Glycerol	Contact between the two may produce an explosion.
	Merck Index, 7th Ed., p. 489 (1960). *Pieters,* p. 30 (1957).
Lithium	See LITHIUM plus Chromic Oxide.
Oxygen Difluoride	See OXYGEN DIFLUORIDE plus Aluminum Chloride.

CHROMIUM iii OXIDE

(See CHROMIUM OXIDE)

CHROMIUM vi OXIDE

(See CHROMIC ANHYDRIDE)

CHROMIUM SESQUIOXIDE

(See CHROMIUM OXIDE)

CHROMIUM TETRACHLORIDE $CrCl_4$

Potassium	See POTASSIUM plus Aluminum Bromide.
Sodium	See SODIUM plus Chromium Tetrachloride.

CHROMIUM TRIAMMINOTETROXIDE $Cr(NH_3)_3O_4$

(self-reactive)	Chromium triamminotetroxide detonates and becomes incandescent when heated.
	Mellor **11:** (1946-1947).

CHROMIUM TRICHLORIDE $CrCl_3$

Lithium	See LITHIUM plus Chromium Trichloride.

CHROMIUM TRIFLUORIDE CrF_3

Potassium	See POTASSIUM plus Ammonium Bromide.

CHROMIUM TRIOXIDE

(See CHROMIC ANHYDRIDE)

CHROMOUS OXIDE CrO

Air	Chromous monoxide is spontaneously flammable in air.
	Ellern (1968).

CHROMOUS SULFIDE CrS

Chromic Anhydride	See CHROMIC ANHYDRIDE plus Chromous Sulfide.
Fluorine	See FLUORINE plus Chromous Sulfide.

CHROMYL CHLORIDE CrO_2Cl_2

Acetone	Alcohol, ether and acetone react with chromyl chloride with incandescence. Turpentine is ignited by chromyl chloride.
	Mellor **11:** 396 (1946-1947).
Ammonia	Chromyl chloride causes ammonia and ethyl alcohol to

	ignite.
	Durrant, p. 991 (1962).
Chlorine and Carbon	See CHLORINE plus Chromyl Chloride and Carbon.
Diethyl Ether	See CHROMYL CHLORIDE plus Acetone.
Ethyl Alcohol	See CHROMYL CHLORIDE plus Ammonia.
Fluorine	See FLUORINE plus Chromyl Chloride.
Phosphorus	See PHOSPHORUS plus Chromyl Chloride.
Phosphorus Trichloride	Each drop of chromyl chloride added to well-cooled phosphorus trichloride produces a hissing noise, incandescence, and sometimes an explosion.
	Mellor **11:** 395 (1946-1947).
Sodium Azide	See SODIUM AZIDE plus Chromyl Chloride.
Sulfur	See SULFUR plus Chromyl Chloride.
Sulfur Monochloride	If chromyl chloride vapor is passed through a narrow jet into the vapor of sulfur monochloride, vivid combustion occurs.
	Mellor **11:** 394 (1946-1947).
Turpentine	See CHROMYL CHLORIDE plus Acetone.

COBALT Co

Acetylene	Pyrophoric cobalt decomposes acetylene in the cold and the metal becomes incandescent.
	Mellor **14:** 513 (1946-1947).
Air	Pyrophoric cobalt, a black powder, burns brilliantly when exposed to air.
	Mellor **14:** 453 (1946-1947).
Ammonium Nitrate	See AMMONIUM NITRATE plus Metals (powdered).

COBALT ALLOYS See LITHIUM plus Cobalt Alloys.

COBALT-HEXAMMINE CHLORATE $Co(NH_3)_6(ClO_3)_2$

(self-reactive)	This compound detonates when struck.
	Mellor **2, Supp. 1:** 592 (1956).

COBALT-HEXAMMINE CHLORITE $Co(NH_3)_6ClO_23H_2O$

(self-reactive)	Hexamminocobaltic chlorite contains an explosive combination of ions.
	Mellor **2, Supp. 1:** 575 (1956).
	Cobalt ammine azides explode violently on impact.
	Mellor **8, Supp. 2:** 48 (1967).

COBALT-HEXAMMINE PERCHLORATE $Co(NH_3)_6(ClO_4)_2$

(self-reactive)	This compound detonates when struck but is less sensitive than hexamminocobalt chlorate.
	Mellor **2, Supp. 1:** 592 (1956).

COBALT NITRIDE CoN

Air	Cobalt nitride is spontaneously flammable in air.
	Brauer (1965).
	Mellor **8, Supp. 1:** 238 (1964).

COBALT-PENTAMMINE AZIDE PERCHLORATE

$[Co(NH_3)_5N_3](ClO_4)_2$

Phenyl Isocyanate and Nitrosyl Perchlorate	See PHENYL ISOCYANATE plus Cobalt Pentammine Triazo Perchlorate and Nitrosyl Perchlorate.

COBALT-PENTAMMINE HYPOPHOSPHITE PERCHLORATE

$[Co(NH_3)_5]H_2PO_2(ClO_4)_2$

(self-reactive)	When a chemist touched a platinum wire (temperature uncertain) into the freshly prepared chemical to make a flame test, the preparation exploded.
	Serious Acc. Series **253** (1965).

COBALT TRIPHOSPHINE

(See COBALTIC DIHYDROPHOSPHIDE)

COBALTIC DIHYDROPHOSPHIDE $Co(PH_2)_3$

Air	Cobalt triphosphine is spontaneously flammable in air.
	J. Zehr, *Staub* **22** (11): 494-508 (1962).

COBALTIC FLUORIDE CoF_3

Silicon	See SILICON plus Colbatic Fluoride.

COBALTIC-HEXAMMINE IODATE $[Co(NH_3)_6](IO_3)_3$

(self-reactive)	Hexammine cobalt iodate explodes at 355¡ C and is impact sensitive.
	W. R. Tomlinson, Jr. and L. F. Audrieth,
	J. Chem. Edu. **27:** 606-609 (1950).

COBALTIC-HEXAMMINE PERCHLORATE $[Co(NH_3)_6](ClO_4)_3$

(self-reactive)	Hexammine cobalt perchlorate explodes at 360¡ C and is impact sensitive.
	W. R. Tomlinson, Jr. and L. F. Audrieth,

J. Chem. Edu. **27:** 606-609 (1950).

COBALTIC-PENTAMMINE AZIDE $CoN_3(NH_3)_5(N_3)_2$

(self-reactive)	Cobalt ammine azide exploded violently on impact.
	Mellor **8, Supp. 4:** 48 (1967).

COBALTIC-PENTAMMINE CHLORITE $Co(NH_3)_5Cl(ClO_2)_2$

(self-reactive)	Pentamminochlorocobaltic chlorite contains an explosive combination of ions.
	Mellor **2, Supp. 1:** 575 (1956).

COBALTIC-TETRAMMINE AZIDE $Co(N_3)_2(NH_3)_4N_3$

(self-reactive)	See COBALTIC-PENTAMMINE AZIDE (self-reactive).

COBALTIC-TRIAMMINE AZIDE $Co(N_3)_3(NH_3)_3$

(self-reactive)	See COBALTIC-PENTAMMINE AZIDE (self-reactive)

COBALTOUS BROMIDE $CoBr_2$

Potassium	See POTASSIUM plus Boron Tribromide.
Sodium	See SODIUM plus Cobaltous Bromide.

COBALTOUS CHLORIDE $CoCl_2$

COBALTOUS CYANIDE $Co(CN)_2$

Magnesium	See MAGNESIUM plus Cadmium Cyanide.

COBALTOUS HYPOPHOSPHITE $CO(PH_2O_2)_2$

(self-reactive) | Cobaltous hypophosphite liberates spontaneously flammable phosphine above 150¡ C.

Mellor **8:** 889 (1946-1947).

COBALTOUS-PENTAMMINE CHLORO-PERCHLORATE

$[Co(NH_3)_5Cl]ClO_4$

(self-reactive) | Cobaltous-pentammine chloro-perchlorate explodes at 320¡C and is impact sensitive.

J. Chem. Educ. **27:** 606-609 (1950).

COBALTOUS-PENTAMMINE NITRITO-N NITRATE

$[Co(NH_3)_5NO_2]NO_3$

(self-reactive) | Nitropentammine cobalt nitrate explodes at 310¡C and is impact sensitive.

W. R. Tomlinson, Jr. and L. F. Audrieth,

J. Chem. Edu. **27:** 606-609 (1950).

COBALTOUS-TRIHYDRAZINE CHLORATE $CO(N_2H_4)_3(ClO_3)_2$

(self-reactive) | This compound detonates when struck.

Mellor **2, Supp. 1:** 592 (1956).

COKE

Fluorine | See FLUORINE plus Common Materials and Oxygen.

COPPER Cu

Acetylene | Unstable acetylides form when acetylene is passed over copper that has been heated enough to form a tarnish of oxide coating. In the presence of wet acetylene and

	ammonia, copper and brasses down to 60 per cent copper react readily to form explosive acetylides.
	Brameld, Clark and Seyfond, *J. Soc. Chem. Ind.* **66:** 346-53 (1947). G. Benson, *Comp. Gas Bull.* 1950-83. *Miller,* pp. 484-6 (1965). *Rutledge,* p. 84 (1968).
Ammonium Nitrate	See AMMONIUM NITRATE plus Metals (powdered).
	Mellor **8, Supp. 1:** 546 (1964).
Barium Bromate	See COPPER plus Bromates.
Barium Chlorate	See COPPER plus Bromates.
Barium Iodate	See COPPER plus Bromates.
Bromates	A combination of finely divided copper with finely divided bromates (also chlorates or iodates) of barium, calcium, magnesium, potassium, sodium, or zinc will explode with heat, percussion, and sometimes light friction.
	Mellor **2:** 310 (1946-1947).
Calcium Bromate	See COPPER plus Bromates.
Calcium Chlorate	See COPPER plus Bromates.
Calcium Iodate	See COPPER plus Bromates.
Chlorates	See COPPER plus Bromates.
Chlorine	Copper foil burns spontaneously in gaseous chlorine.
	Mellor **2:** 92, 95 (1946-1947). *Mellor* **9:** 626 (1946-1947).
	Copper reacts vigorously with chlorine at around 320¡ C.
	Mellor **2, Supp. 1:** 380 (1956).
Chlorine and Oxygen Difluoride	See CHLORINE plus Oxygen Difluoride.
Chlorine Trifluoride	See ALUMINUM plus Chlorine Trifluoride.
Ethylene Oxide	Copper and other acetylide-forming metals should not be used in process equipment handling ethylene oxide because of the danger of the possible presence of acetylene. See COPPER plus Acetylene.
	L. G. Hess and V. V. Tilton, *Ind. Eng. Chem.* **42:** 1251-8

	(1950).
Fluorine	See FLUORINE plus Copper. See also FLUORINE plus Metals.
Hydrazine Mononitrate	See ZINC plus Hydrazine Mononitrate.
Hydrazoic Acid	Explosions resulted from corrosion of brass parts of a vacuum gage and water jet vacuum pump on prolonged contact with hydrozoic acid vapors.
	Chem. & Ind. **10,** p. 444 (1973).
Hydrogen Peroxide	See IRON plus Hydrogen Peroxide.
Hydrogen Sulfide	If a mixture of air and hydrogen sulfide is passed over powdered copper, the mixture may heat to redness.
	Mellor **10:** 140 (1946-1947).
Iodates	See COPPER plus Bromates.
Lead Azide	Lead azide, when in contact with copper, zinc, or alloys containing copper or zinc, forms, over a period of time, the extremely sensitive copper and zinc azides which on slight disturbance can set off the main body of lead azide.
	Federoff **1:** A532, A551 (1960).
	Mustaparta (1966).
Magnesium Bromate	See COPPER plus Bromates.
Magnesium Chlorate	See COPPER plus Bromates.
Magnesium Iodate	See COPPER plus Bromates.
Phosphorus	The reacting mass formed by the mixture of phosphorus and copper, iron, nickel, or platinum can become incandescent when heated.
	Mellor **8, Supp. 3:** 228 (1971).
Potassium Bromate	See COPPER plus Bromates.
Potassium Chlorate	See COPPER plus Bromates.
Potassium Iodate	See COPPER plus Bromates.
Potassium Peroxide	See POTASSIUM plus Potassium Peroxide and POTASSIUM plus Potassium Tetroxide.

Sodium Azide	See SODIUM AZIDE plus Copper.
Sodium Bromate	See COPPER plus Bromates.
Sodium Chlorate	See COPPER plus Bromates.
Sodium Iodate	See COPPER plus Bromates.
Sodium Peroxide	Sodium peroxide oxidizes copper with incandescence. *Mellor* **2:** 490-93 (1946-1947).
Sulfur and Chlorates	See SULFUR plus Chlorates and Copper.
Zinc Bromate	See COPPER plus Bromates.
Zinc Chlorate	See COPPER plus Bromates.
Zinc Iodate	See COPPER plus Bromates.

COPPER ACETYLIDE

(See CUPROUS CARBIDE)

COPPER ALUMINOHYDRIDE

(See CUPROUS TETRAHYDROALUMINATE)

COPPER CYANIDE CuCN

(See CUPROUS CYANIDE)

COPPER METHYL CH_3Cu

(See METHYL COPPER)

COPPER OXIDE CuO

(See CUPRIC OXIDE)

COPPER OXYCHLORIDE Cu_2OCl_2

Potassium	See POTASSIUM plus Boric Acid.

COPPER SALTS

Acetylene	Many copper salts form dangerous acetylides. The copper acetylides formed in ammoniacal or caustic solutions with cupric salts and acetylene are more explosive than those derived from cuprous salts.
	Brameld, Clark and Seyfond, *J. Soc. Chem. Ind.* **66:** 346-53 (1947). G. Benson, *Comp. Gas Bull.* 1950-83. *Miller,* pp. 484-6 (1965).
Hydrazine	Copper salts promote the decomposition of hydrazine.
	Chem. Eng. News **48** (48): 97 (Nov. 16, 1970). See also CUPRIC OXIDE plus Hydrazine.
Nitromethane	Nitromethane and salts of copper, silver, gold or mercury spontaneously form explosive materials.
	Chem. Eng. News **49** (23): 6 (1971).

CREOSOTE OIL

Chlorosulfonic Acid	See CHLOROSULFURIC ACID plus Creosote Oil.

CRESOL $CH_3C_6H_4OH$

Chlorosulfonic Acid	Mixing cresol and chlorosulfonic acid in a closed container caused the temperature and pressure to increase.
	Flynn and Rossow (1970). See Note under complete reference.
Nitric Acid	Mixing cresol and 70% nitric acid in a closed container caused the temperature and pressure to increase.
	Flynn and Rossow (1970). See Note under complete reference.
Oleum	Mixing cresol and oleum in a closed container caused the temperature and pressure to increase.
	Flynn and Rossow (1970). See Note under complete

reference.

CROTONALDEHYDE $CH_3CH=CHCHO$

Butadiene-1,3	See BUTADIENE-1,3 plus Crotonaldehyde.

CUMENE $C_6H_5CH(CH_3)_2$

Chlorosulfonic Acid	Mixing Cumene and chlorosulfonic acid in a closed container caused the temperature and pressure to increase. *Flynn and Rossow* (1970). See Note under complete reference.
Nitric Acid	Mixing cumene and 70% nitric acid in a closed container caused the temperature and pressure to increase. *Flynn and Rossow* (1970). See Note under complete reference.
Oleum	Mixing cumene and oleum in a closed container caused the temperature and pressure to increase. *Flynn and Rossow* (1970). See Note under complete reference.

CUMENE HYDROPEROXIDE $C_6H_5C(CH_3)_2OOH$

(self-reactive)	At concentrations of 91 and 95%, cumene hydroperoxide decomposed violently at about 150¡ C. A. Le Roux, *Mem. Poudres* **37:** 49-58 (1955).

CUPRIC AZIDE $CU(N_3)_2$

(self-reactive)	Spontaneous explosions have been observed with this compound. *Mellor* **8, Supp. 2:** 50 (1967). See SODIUM AZIDE plus Copper.

CUPRIC BROMIDE $CuBr_2$

Potassium	See POTASSIUM plus Aluminum Bromide.

CUPRIC CHLORIDE $CuCl_2$

Potassium	See POTASSIUM plus Aluminum Bromide.
Sodium	See SODIUM plus Aluminum Bromide.

CUPRIC CHLORITE $Cu(ClO_2)_2$

(self-reactive)

Cupric chlorite explodes violently on percussion. In the dry state it decomposes within 12 days.

Mellor **2, Supp. 1:** 574 (1956).

CUPRIC-DIHYDRAZINE CHLORATE $Cu(H_2NNH_2)_2ClO_3$

(self-reactive)

This is an extremely explosive salt and will detonate on drying.

Mellor **8, Supp. 2:** 88 (1967).

Mellor **2, Supp. 1:** 592 (1956).

CUPRIC HYPOPHOSPHITE $Cu(PH_2O_2)_2$

(self-reactive)

Cupric hypophosphite forms impact-sensitive ammunition-priming mixtures.

Mellor **8, Supp. 3:** 623 (1971).

Cupric hypophosphite explodes suddenly at about 90¡ C.

Mellor **8:** 883 (1946-1947).

CUPRIC NITRATE $Cu(NO_3)_2$

Paper

On prolonged contact with cupric nitrate in the presence of moisture paper will ignite spontaneously.

	Ellern, p. 46 (1968).
Potassium Ferrocyanide	A finely ground mixture of potassium ferrocyanide and cupric nitrate when dried at 220¡ C exploded within a few minutes.
	Chem. Abst. **77:** 13431f (1972).
Tin	See TIN plus Cupric Nitrate.

CUPRIC NITRIDE Cu_3N_2

Nitric Acid	Concentrated nitric acid plus cupric nitride explodes with great violence.
	Mellor **8:** 100 (1946-1947).

CUPRIC OXIDE CuO

Aluminum	See ALUMINUM plus Copper Oxide.
Boron	See BORON plus Cupric Oxide.
Cesium Acetylene Carbide	See CESIUM ACETYLENE CARBIDE plus Cupric Oxide.
Hydrazine	Hydrazine reacts vigorously with cupric oxide.
	Mellor **3:** 137 (1946-1947).
Magnesium	See MAGNESIUM plus Cupric Oxide.
Phospham	See PHOSPHAM plus Cupric Oxide.
Potassium	See POTASSIUM plus Cupric Oxide.
Rubidium Acetylene Carbide	See RUBIDIUM ACETYLENE CARBIDE plus Cupric Oxide.
Sodium	See SODIUM plus Cupric Oxide.
Titanium	See TITANIUM plus Cupric Oxide.
Zirconium	See ZIRCONIUM plus Cupric Oxide.

CUPRIC PHOSPHIDE Cu_3P_2

Potassium Chlorate	When copper phosphide is mixed with oxidizing agents, such as potassium chlorate, it explodes on impact.
	Mellor **8:** 839 (1946-1947).
Potassium Nitrate	When copper phosphide is mixed with potassium nitrate and heated, an explosion occurs.
	Mellor **8:** 839 (1946-1947).
Water	On contact with water, copper phosphide yields phosphine, which is spontaneously flammable.
	Schwab (1970).

CUPRIC SALTS

Sodium Hypobromite	See SODIUM HYPOBROMITE plus Cupric Salts.

CUPRIC SULFATE $CuSO_4$

Hydroxylamine	Anhydrous copper sulfate causes hydroxylamine to ignite and the hydrated salt is vigorously reduced.
	Mellor **8:** 292 (1946-1947).
Magnesium	See MAGNESIUM plus Cupric Sulfate.

CUPRIC SULFIDE CuS

Cadmium Chlorate	Copper sulfide explodes on contact with a concentrated solution of chloric acid or chlorates of cadmium, magnesium, or zinc.
	Mellor **Supp. II, Part I:** 584 (1956).
Chlorates	See COPPER SULFIDE plus Cadmium Chlorate.
Chloric Acid	See COPPER SULFIDE plus Cadmium Chlorate.
Hydrogen Peroxide	See ANTIMONY TRISULFIDE plus Hydrogen Peroxide.
Magnesium, Ammonium	See MAGNESIUM plus Copper Sulfate

Nitrate, Potassium Chlorate and Water	(anhydrous), Ammonium Nitrate, Potassium Chlorate and Water.
Magnesium Chlorate	See COPPER SULFIDE plus Cadmium Chlorate.
Zinc Chlorate	See COPPER SULFIDE plus Cadmium Chlorate.

CUPRIC-TETRAMMINE CHLORATE $Cu(NH_3)_4(ClO_3)_2$

(self-reactive)	This compound will detonate when struck. *Mellor* **2, Supp. 1:** 592 (1956).

CUPRIC-TETRAMMINE PERCHLORATE $Cu(NH_3)_4(ClO_4)_2$

(self-reactive)	This compound will detonate when struck but is less sensitive than tetramminocupric chlorate. *Mellor* **2, Supp. 1:** 592 (1956).

CUPROUS AZIDE CuN_3

(self-reactive)	Cuprous azide decomposes at 205¡ C. It is explosively unstable. *Mellor* **8, Supp. 2:** 43 (1967).

CUPROUS BROMIDE CuBr

Potassium	See POTASSIUM plus Aluminum Bromide.

CUPROUS CARBIDE Cu_2C_2

(self-reactive)	Cuprous acetylide is explosive and can be detonated by percussion or when heated above 100¡C. *Mellor* **5:** 851, 852 (1946-1947). *Rutledge,* p. 84 (1968).
Acetylene	If warmed in air or oxygen for several hours, it explodes

	when brought in contact with acetylene.
	Mellor **5:** 851, 852 (1946-1947).
Bromine	See BROMINE plus Cuprous Acetylide.
Chlorine	See BROMINE plus Cuprous Acetylide.
Iodine	See BROMINE plus Cuprous Acetylide.
Silver Nitrate	Cuprous acetylide and silver nitrate give off an explosive mixture.
	Mellor **5:** 853 (1946-1947). J. K. Luchs, *Photo. Sci. Eng.* **10** (6): 334-7 (1966).

CUPROUS CHLORIDE CuCl

Potassium	See POTASSIUM plus Aluminum Bromide.

CUPROUS CYANIDE CuCN

Magnesium	See MAGNESIUM plus Cadmium Cyanide.

CUPROUS HYDRIDE Cu_2H_2

Air	Dry copper hydride is spontaneously flammable in air.
	Von Schwartz, p. 156 (1964).
Bromine	See BROMINE plus Copper Hydride.
Chlorine	See BROMINE plus Copper Hydride.
Fluorine	See BROMINE plus Copper Hydride.

CUPROUS IODIDE CuI

Potassium	See POTASSIUM plus Aluminum Bromide.

CUPROUS NITRIDE Cu_3N

Nitric Acid	See CUPRIC NITRIDE plus Nitric Acid.

	See CUPROUS NITRIDE plus Sulfuric Acid.
Sulfuric Acid	The reaction of cuprous nitride and sulfuric or nitric acid is violent.
	Mellor **8, Supp. 1:** 154 (1964).

CUPROUS TETRAHYDROALUMINATE $CuAlH_4$

Air	Copper aluminohydride is spontaneously flammable in air.
	J. Aubrey and G. Monnier, *Comp. Rend.* **238:** 2534-2535 (1954).

CYANIDES

(See also specific cyanides as primary entries or under other reactants)

Chlorates	Violent explosion occurs if cyanide salt is melted with nitrite salt. The melt explodes if cyanide plus chlorate or nitrite is heated to 450¡C.
	Von Schwartz, pp. 299, 327 (1918).
	Also see ANTIMONY SULFIDE plus Chlorates.
Fluorine	See FLUORINE plus Chlorides.
Magnesium	See MAGNESIUM plus Cadmium Cyanide.
Nitrates	See NITRATES plus Cyanides.
Nitric Acid	See NITRIC ACID plus Cyanides.
Nitrites	See CYANIDES plus Chlorates.
	See NITRITES plus Potassium Cyanide.

CYANOACETIC ACID $NCCH_2COOH$

Furfuryl Alcohol	See FURFURYL ALCOHOL plus Cyanoacetic Acid.

CYANOACETYL CHLORIDE $NCCH_2COCl$

(self-reactive)	Cyanoacetyl chloride was prepared from cyanoacetic acid

and phosphorus pentachloride. Following distillation of the volatile material, the crude cyanoacetyl chloride was placed in a hood in a stoppered, 1-liter flask. About 24 hours later the flask exploded.

Wischmeyer (1967).

CYANODIMETHYLARSINE $(CH_3)AsCN$

Air	Dimethylcyanoarsine is spontaneously flammable in air.
	Ripley (1966).

2-CYANOETHANOL $HOCH_2CH_2CN$

Sulfuric Acid	Concentrated sulfuric acid reacts violently with both ethylene cyanohydrin and epichlorohydrin.
	Confidential information furnished to NFPA.

CYANOGEN NCCN

Fluorine	See FLUORINE plus Cyanogen.
Oxygen	See OXYGEN (LIQUID) plus Cyanogen.

CYANOGEN AZIDE NCNNN

(self-reactive)	Cyanogen azide explodes when shocked mechanically or thermally.
	Chem. Eng. News **43** (52): 29, 30 (Dec. 27, 1965).

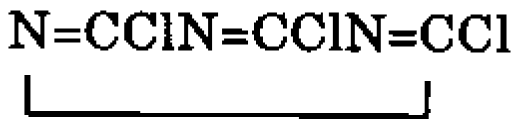
CYANOGEN IODIDE NCI

Phosphorus	See PHOSPHORUS plus Cyanogen Iodide.

CYANURIC ACID

Ethyl Alcohol — See CYANURIC ACID plus Water.

CYANURIC CHLORIDE



Dimethyl Sulfoxide — See DIMETHYL SULFOXIDE plus Acyl Halides.

Water — Cyanuric chloride acts autocatalytically with water at a temperature of about 30¡ C to produce cyanuric acid, hydrochloric acid and heat. An explosion occurred during an industrial process in which cyanuric chloride and water were mixed. The refrigeration had been turned off. Pressure built up in the reactor and blew gaskets, allowing flammable vapors to fill the building. The explosion occurred when the vapors were ignited.

MCA Case History **1869** (1972).

CYCLOHEXANE C_6H_{12}

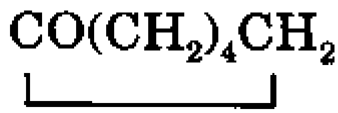
Nitrogen Dioxide — Through an error, liquid nitrogen dioxide instead of gaseous was fed into a nitration column containing hot cyclohexane. An explosion resulted.

MCA Case History **128** (1962).

CYCLOHEXANOL $C_6H_{11}OH$

Nitric Acid — See NITRIC ACID plus Cyclohexanol.

CYCLOHEXANONE



Nitric Acid — See NITRIC ACID plus Cyclohexanone.

CYCLOPENTADIENYLCHROMIUM DINITROSYL DIMER

$[C_5H_5(NO)_2Cr]_2$

(self-reactive) — A glass vial of the dimer in the sample compartment of a laser Raman spectrophotometer exploded on excitation by the helium-neon beam.

Chem. & Ind. No. **7:** 201 (1969). R. B. King and M. B. Bisnette, *Inorg. Chem.* **3:** 79 (1964).

DECABORANE (14) $B_{10}H_{14}$

Oxygen — See OXYGEN plus Decaborane.

DEXTROSE $C_6H_{12}O_6$

Sodium Peroxide and Potassium Nitrate — See SODIUM PEROXIDE plus Dextrose and Potassium Nitrate.

DIACETYLENE

(See BUTADIYNE)

DIACETYL PEROXIDE $(CH_3CO)_2O_2$

(self-reactive) — Acetyl peroxide is unpredictable. Five grains of it being removed from an ice chest detonated violently.

Chem. Eng. News **26:** 3197 (1948).

	Pure diacetyl peroxide is a severe explosion hazard.
	Cond. Chem. Dict. **10:** (1971).
	See also HYDROGEN PEROXIDE plus Acetic Anhydride.
Diethyl Ether	Solid acetyl peroxide in contact with ether or any volatile solvent may explode violently. A 5-gram portion in ether detonated while being carried.
	L. P. Kuhn, *Chem. Eng. News* **26:** 3197 (1948); E.S. Shanley, *Chem. Eng. News* **27:** 175 (1949).
Organic Materials	See ACETYL PEROXIDE plus Solvents.
Solvents	Acetyl peroxide is extremely shock-sensitive. When a solution of acetyl peroxide in any volatile solvent is evaporated, the concentration may become high enough for spontaneous explosions. Acetyl peroxide is a powerful oxidizing agent; it may cause ignition of organic materials on contact.
	Chem. Eng. News **26:** 3197 (1948). *Chem. Eng. News* **27:** 175 (1949).

DIALKYLPHOSPHINES

Chlorine	See CHLORINE plus Alkylphosphines.

DIALLYL METHYL CARBINOL $(CH_2{=}CHCH_{2-})_2C(OH)CH_3$

Ozone and Acetic Acid	During the preparation of β-hydroxy-β-methyl glutaric acid using 75 grams of diallyl methyl carbinol, the material had been ozonized and allowed to stand overnight. Glacial acetic acid had been added and the mixture was being concentrated under vacuum in a desiccator. After 1 $^1/_2$ hours the mixture exploded. Previous preparations using 12.6 grams were successful.
	Chem. Eng. News. **51** (6): 29 (Feb. 5, 1973).

DIALLYL PHOSPHITE $(C_3H_5O)_2POH$

(self-reactive)	Diallyl phosphite is made from allyl alcohol and

phosphorus trichloride. When the product is distilled in vacuo in a carbon dioxide stream, explosions usually occur after about two-thirds is distilled.

Zh. Obshch. Khim. **21:** 658-62 (1951).

DIAMIDOPHOSPHOROUS ACID $POH(NH_2)_2$

Water	This material dissolves in water with such violence that the mass becomes incandescent. *Mellor* **8:** 704 (1946-1947).

DIAZIDO ALKANES

(See AZIDOALKANES)

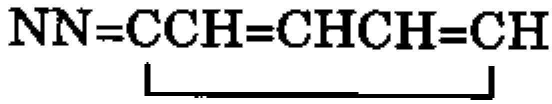
DI-o-AZIDOBENZOYL PEROXIDE $[C_6H_4(N_3)CO]_2O_2$

(self-reactive)	A 2-gram sample of the crystalline material on a sintered glass funnel detonated "with extreme violence" when touched with a metal spatula. A build-up of static charge on the sintered glass may have initiated the decomposition. *Chem. Eng. News* **41** (48): 45; **41** (52): 5 (1963).

1,3-DIAZIDOPROPENE $N_3CH{=}CHCH_2N_3$

(self-reactive)	In the determination of the weight of a sample of 1,3-diazidopropene, a violent explosion occurred. J. H. Bover and F. C. Canter, *Chem. Reviews* **54:** 32, 33 (1954).

DIAZOCYCLOPENTADIENE



(self-reactive) — Diazocyclopentadiene should be handled cautiously since during one preparation a violent explosion took place after distillation.

F. Ranairez and S. Levy, *J. Org. Chem.* **23:** 2036-7 (1958).

DIAZOMALONIC ACID $(HOCO)_2C{=}NN$

(self-reactive) — Six grams of impure diazomalonic acid was being distilled under 3 millimeters pressure in a 50 milliliter flask. After three minutes of heating, during which no product was obtained, the flask exploded.

NSC Newsletter, Campus Safety **3** (1973).

DIAZOMETHANE $NN{=}CH_2$

(self-reactive) — Diazomethane will undergo violent thermal decomposition. Above 200¡ C, the vapor may explode violently. Explosions at low temperatures can occur if traces of organic matter are present.

J. Phys. Chem. **35:** 1493 (1931).

Organic Matter — See DIAZOMETHANE (self-reactive).

DIAZONIUM CHLORIDE SALTS

Sodium Sulfide — See SODIUM SULFIDE plus Diazonium Salts and Diazonium Chloride Salts.

DIAZONIUM PERCHLORATES

(self-reactive) — Diazonium perchlorates are particularly hazardous, being exploded by the slightest shock when dry.

Berichte **39:** 3146-8 (1906). *German Pat.* 258,679 (Apr.

	27, 1911). *ACS* **146:** 213.

DIAZONIUM SALTS

Sodium Bisulfide	See DIAZONIUM SALTS plus Thiophenates.
Sodium Sulfide	See SODIUM SULFIDE plus Diazonium Salts and Diazonium Chloride Salts.
	See DIAZONIUM SALTS plus Thiophenates.
Thiophenates	This reaction is often quoted as a route to diaryl sulfides without mention of explosive hazards. Unstable p-chlorodiazobenzene thiophenyl ether has been prepared by this route. Two reactions of this type were attempted and in both cases explosive compounds were produced. Also, reported explosions from reactions of diazonium salts with xanthates, sodium bisulfide, and sodium sulfide are attributed to formation of diazo ethers or related compounds.
	BCISC **40** (158): 17-18 (1969).
Xanthates	See DIAZONIUM SALTS plus Thiophenates.

DIBENZOYL PEROXIDE $(C_6H_5CO)_2O_2$

N,N-Dimethylaniline	Explosive decomposition occurred when finely ground benzoyl peroxide was allowed to react with N,N-dimethylaniline by breaking an ampoule containing 0.5 grams of dimethylaniline in an autoclave.
	L. Horner and C. Betzel, *Chem. Ber*. **86:** 1071-72 (1953).
Lithium Aluminum Hydride	An attempted reduction of benzoyl peroxide with lithium aluminum hydride resulted in an explosion.
	D.A. Sutton, *Chem. & Ind.* **1951:** 272 (1951).

DIBENZYL CHLOROPHOSPHONATE $(C_6H_5CH_2O)_2POCl$

(self-reactive)	Dibenzylchlorophosphonate can decompose violently during vacuum distillation.

Chem. Eng. News **28:** 3452 (Oct. 2, 1950).

J. Chem. Soc. 1106-10 (1948).

DIBENZYL PHOSPHITE $(C_6H_5CH_2O)_2PHO$

(self-reactive)	Dibenzyl phosphite can decompose violently during vacuum distillation.
	Chem. Eng. News **28:** 3452 (Oct. 2, 1950).
	J. Chem. Soc. **385** (1945).

DIBORANE $BH_2(H_2)BH_2$

Aluminum	See ALUMINUM plus Diborane.
Carbon Tetrachloride	See CARBON TETRACHLORIDE plus Diborane.
Chlorine	See CHLORINE plus Diborane.
Halogenated Hydrocarbons	Diborane reacts violently with halogenated hydrocarbons (as in vaporizing liquid fire extinguishing agents).
	Haz. Chem. Data (1966).
Nitric Acid	See NITRIC ACID plus Diborane.
Nitrogen Trifluoride	See NITROGEN TRIFLUORIDE plus Diborane.
Oxygen	See OXYGEN plus Diborane.
Phosphorus Trifluoride	See PHOSPHORUS TRIFLUORIDE plus Diborane.
Water	Diborane ignites spontaneously in moist air.
	Haz. Chem. Data (1966). E. L. Poling and H. P. Simons, *Ind. Eng. Chem.* **50:** 1695-1698 (1958). P. L. Sampl and H. P. Simons, *Ind. Eng. Chem.* **50:** 1699-1702 (1958).

DIBORON TETRACHLORIDE

(See TETRACHLORODIBORANE)

2,6-DIBROMO-p-BENZOQUINONE-4-CHLORIMINE

$O{=}C_6H_2Br_2{=}NCL$

(self-reactive)

While thin layer chromatograms were being dried with a hot-air dryer, a 25-gram bottle of 2,6-dibromo-p-benzoquinone-4-chlorimine, one to two feet away, exploded.

Chem. & Ind. **37:** 1551 (1967).

DIBROMOBORYL-PHOSPHINE Br_2BPH_2

Air

Dibromoborine phosphine is spontaneously flammable in air.

Douda (1966).

2,6-DIBROMO-N-CHLOROBENZOQUINONIMINE

$OC_6H_2(Br)_2NCl$

(self-reactive)

This chromatographic reagent can decompose violently under readily obtainable laboratory conditions. After a small quantity exploded on a laboratory reagent shelf, tests were made on one-half-gram quantities in a thermal stability bomb. When the temperature was raised gradually to 120¡ C, a violent exothermic reaction raised the pressure to 1,800 psi and burst the rupture diaphragm. A second sample held at 60¡ C decomposed similarly after 3 hours. Tests on the chlorocompound 2,6-DICHLOROQUINONECHLORIMIDE showed similar, but less severe instability.

Chem. Eng. News **45** (50):54 (Dec. 11, 1967).

Chem. & Ind. **37:** 1551 (Sept. 1967).

DIBROMO-3,5-DIMETHOXYANILINE $(CH_3O)_2C_6HBr_2NH_2$

(self-reactive)

See 2-BROMO-3,5-DIMETHOXYANILINE (self-reactive).

DIBROMOMALONONITRILE $CBr_2(CN)_2$

Sodium Azide	See SODIUM AZIDE plus Dibromomalononitrile.

DIBROMOTRIMETHYLALUMINUM $(CH_3)_3AlBr_2$

Air	Trimethyl aluminum bromide is spontaneously flammable in air. *Chem. Eng. Progs.* **63** (7): 126 (1967).

DIBUTYLCHLOROBORANE $(C_4H_9)_2BCl$

Air	Dibutyl boron chloride is spontaneously flammable in air. *Buls, Bimonthly Rept.* **8**, p. 4 (1953).

DIBUTYL ETHER $C_4H_9OC_4H_9$

Nitrogen Trichloride	See NITROGEN TRICHLORIDE plus Di-n-Butyl Ether.

DIBUTYLMAGNESIUM $(C_4H_9)_2Mg$

Air	Dibutyl magnesium is spontaneously flammable in air. *Douda* (1966).

2,6-DI-t-BUTYL-4 NITROPHENOL $HOC_6H_3[C(CH_3)\ 2CH_3]_2$

(self-reactive)	This material exploded violently after being warmed for two to three minutes on a steam bath. *ASESB Expl. Report* **24** (1961).

2,6-DI-t-BUTYLPHENOL $HOC_6H_3[C(CH_3)_2CH_3]_2$

Nitric Acid	See NITRIC ACID plus Di-t-Butylphenol.

DIBUTYL PHTHALATE $(C_4H_9OCO)_2C_6H_4$

Chlorine	See CHLORINE plus Polypropylene.

DIBUTYL SULFOXIDE $(C_4H_9)_2SO$

Perchloric Acid	See PERCHLORIC ACID plus Dibutyl Sulfoxide.

DICHLORINE HEPTOXIDE Cl_2O_7

(self-reactive)	Dichlorine heptoxide explodes violently under a blow or when heated rapidly.
	Mellor **2, Supp. 1:** 542 (1956).

DICHLOROACETYLENE ClC=CCl

(self-reactive)	During synthesis of dichloroacetylene, the dichloroacetylene accidentally condensed and collected in a water trap. When the chemist attempted to sample the material in the trap, a violent explosion occurred. Since dichloroacetylene is reported to be shock-sensitive, the touching of the sample could have initiated the detonation.
	MCA Case History **1989** (1974).
Air	Dichloroacetylene ignites or explodes on contact with air.
	MCA Case History **495** (1956); **1065** (1965).
	When moist chlorine was passed over calcium carbide and potassium hydroxide, a solution of 58% dichloroacetylene was collected in ether. The solution burned spontaneously and filled the laboratory with phosgene. When the head was removed from a steel bomb used for one of the experiments, contact with air caused an explosion that drove the base of the bomb through the floor.
	R. Reemschneider and K. Brendel, *Ann. Chem.* **640:** 5(1961). *Rutledge*, p. 138 (1968).

DICHLOROBENZENE ClC_6H_4Cl

Aluminum	See ALUMINUM plus Ethylene Dichloride, Propylene Dichloride, and Orthodichlorobenzene.

DICHLORODIETHYLDIAMMINE COBALT PERCHLORATE

$[Co(Cl)_2(C_2H_5)_2(NH_2)_2]ClO_4$

(self-reactive)	Dichlorodiethyldiammine cobalt perchlorate explodes at 300¡C and is impact sensitive.
	W. R. Tomlinson, Jr., and L. F. Audrieth, *J. Chem. Edu.* **27:** 606-609 (1950).

DICHLORODIFLUOROMETHANE CCl_2F_2

Aluminum	See ALUMINUM plus Dichlorodifluoromethane.

DICHLORODIMETHYLSILANE $(CH_3)_2SiCl_2$

Water	Dimethyldichlorosilane reacts violently with water.
	Title 46 (1970).

DICHLORO(DISILYLAMINO)BORANE $(SiH_3)_2NBCl_2$

Air	Disilylamino dichloroborane is spontaneously flammable in air.
	Douda (1966).

1,2-DICHLOROETHANE ClC_2H_4Cl

Aluminum	See ALUMINUM plus Ethylene Dichloride, Propylene Dichloride, and Orthodichlorobenzene.
Nitrogen Tetroxide	See NITROGEN TETROXIDE plus 1,2-Dichloroethane.

DICHLOROETHYLALUMINUM $C_2H_5AlCl_2$

Air	Ethyl aluminum dichloride is spontaneously flammable in

	air.
	Douda (1966).
Benzene and Allyl Chloride	See ALLYL CHLORIDE plus Benzene and Ethyl Aluminum Dichloride.
Toluene and Allyl Chloride	See ALLYL CHLORIDE plus Benzene and Ethyl Aluminum Dichloride.
Water	Ethyl aluminum dichloride reacts violently with water.
	Rose (1961).

DICHLOROETHYLBORANE $C_2H_5BCl_2$

Air	Ethyl boron dichloride is spontaneously flammable in air.
	Buls, Bimonthly Rept. 5, p. 3 (1953).

1,2-DICHLOROETHYLENE ClCH=CHCl

Nitrogen Tetroxide	See NITROGEN TETROXIDE plus 1,2-Dichloroethane.
Potassium Hydroxide	See POTASSIUM HYDROXIDE plus 1,2-Dichloroethylene.
Sodium	See SODIUM plus 1,2-Dichloroethylene.
Sodium Hydroxide	See SODIUM plus 1,2-Dichloroethylene.

DICHLOROFLUORAMINE Cl_2NF

(self-reactive)	Dichlorofluoramine is explosive in the liquid state.
	Lawless and Smith, p. 88 (1968).

1,6-DICHLORO-2,4-HEXADIYNE $(Cl{\bullet}CH_2C{\equiv}C\text{-})_2$

(self-reactive)	1, 6-dichloro-2, 4-hexadiyne is shock-sensitive. P.E. Drieder and H.V. Isaacson,

	Chem. Eng. News **50** (12): 51 (1972).

DICHLOROMETHANE $ClCH_2Cl$

Nitrogen Tetroxide	See NITROGEN TETROXIDE plus 1,2-Dichloroethane.
Oxygen (Liquid)	See OXYGEN (LIQUID) plus Chlorinated Hydrocarbons.
Potassium	See POTASSIUM plus Chloroform.
Sodium	See POTASSIUM plus Chloroform.
Sodium-Potassium Alloy	See SODIUM-POTASSIUM ALLOY plus Carbon Tetrachloride.

N,N-DICHLOROMETHYLAMINE CH_3NCl_2

Sodium Sulfide	N,N-dichloromethylamine exploded violently on addition of sodium sulfide.
	Biul. Wojskowej Akad. Tech. **8** (48): 75-9 (1959).

1,2-DICHLOROPROPANE $ClCH_2CHClCH_3$

Aluminum	See ALUMINUM plus Ethylene Dichloride, Propylene Dichloride and Orthodichlorobenzene. See ALUMINUM plus Propylene Dichloride.

2,6-DICHLOROQUINONECHLORIMIDE

(See 2,6,N-TRICHLORO-BENZOQUINONIMINE)

1,2-DICHLORO-1,1,2,2-TETRAFLUOROETHANE $CClF_2CF_2Cl$

Aluminum	See ALUMINUM plus Dichlorodifluoromethane.

DICYANDIAZIDE $NCN{=}C(NNN)_2$

(self-reactive)	Dicyandiazide is a shock-sensitive compound.

Chem. Eng. News **43** (52): 29, 30 (Dec. 27, 1965).

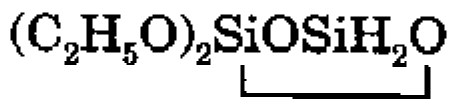
DICYCLOPENTADIENYLIRON

(See FERROCENE)

1,1-DIETHOXY-2-CHLOROETHANE

(See 2-CHLORO-1,1-DIETHOXYETHANE)

2,2-DIETHOXYCYCLODISILOXANE



Air	Diethoxycyclodisiloxane is spontaneously flammable in air. *Kaufman* (1961).

DIETHOXY-SILOXENE

(See 2,2-DIETHOXYCYCLODISILOXANE)

DIETHYL ALUMINUM BROMIDE

(See BROMODIETHYLALUMINUM)

DIETHYL ALUMINUM CHLORIDE

(See CHLORODIETHYLALUMINUM)

DIETHYLALUMINUM HYDRIDE $(C_2H_5)_2AlH$

Air	Diethyl aluminum hydride ignites spontaneously in air.

Fire Haz. Prop. (1969).

DIETHYLARSINE $(C_2H_5)_2AsH$

Air — Diethylarsine is spontaneously flammable in air.

Douda (1966).

DIETHYL AZODICARBOXYLATE $C_2H_5OCON{=}NCOOC_2H_5$

(self-reactive) — A sample decomposed upon attempted distillation with sufficient violence to shatter the distillation apparatus.

Org. Syntheses **28,** p. 59 (1948).

DIETHYL BISMUTH CHLORIDE

(See CHLORODIETHYLBISMUTHINE)

DIETHYL BORON CHLORIDE

(See CHLORODIETHYLBORANE)

DIETHYLCADMIUM $(C_2H_5)_2Cd$

Air — Diethylcadmium fumes explode in air.

Brauer (1965).

DIETHYL (3-DIETHYLAMINOPROPYL) ALUMINUM

$(C_2H_5)_2Al(CH_2)_3N(C_2H_5)_2$

Air — Diethyl 3-diethylaminopropyl aluminum is spontaneously flammable in air.

Douda (1966).

DIETHYLENE GLYCOL DIMETHYL ETHER

(See BIS(2-METHOXYETHYL)ETHER)

DIETHYLENE GLYCOL MONOMETHYL ETHER

(See 2 (2-METHOXYETHOXY) ETHANOL)

DIETHYL ETHER $C_2H_5OC_2H_5$

Acetyl Peroxide	See ACETYL PEROXIDE plus Diethyl Ether.
Air	See OXYGEN plus Diethyl Ether.
Air (Liquid)	A mixture of liquid air and diethyl ether exploded spontaneously.
	Z. Angew. Chem. **40:** 1317. *MCA Case History* **616** (1960).
Bromoazide	See BROMOAZIDE plus Diethyl Ether.
Chlorine	See CHLORINE plus Diethyl Ether.
Chlorine Trifluoride	See CHLORINE TRIFLUORIDE plus Diethy Ether.
Chromic Anhydride	See CHROMIC ANHYDRIDE plus Diethyl Ether.
Chromyl Chloride	See CHROMYL CHLORIDE plus Acetone.
Lithium Aluminum Hydride	See LITHIUM ALUMINUM HYDRIDE plus Diethyl Ether.
Nitrosyl Perchlorate	See NITROSYL PERCHLORATE plus Diethyl Ether.
Nitryl Perchlorate	See NITRYL PERCHLORATE plus Benzene.
Ozone	See OZONE plus Diethyl Ether.
Perchloric Acid	See PERCHLORIC ACID plus Diethyl Ether.
Permanganates and Sulfuric Acid	See PERMANGANATES plus Sulfuric Acid and Benzene.
Potassium Peroxide	See SODIUM PEROXIDE plus Aniline.
Sodium Peroxide	See SODIUM PEROXIDE plus Aniline.

Triethyl Aluminum and Air	See TRIETHYL ALUMINUM plus Diethyl Ether and Air.
Trimethyl Aluminum and Air	See TRIMETHYL ALUMINUM plus Diethyl Ether and Air.

DIETHYL-4-ETHOXYBUTYLAMINE

(See (4-ETHOXYBUTYL) DIETHYLALUMINUM)

DIETHYLMAGNESIUM $(C_2H_5)_2Mg$

Air	Diethyl magnesium is spontaneously flammable in air; it explodes violently on contact with water and will glow and catch fire even in carbon dioxide. It must be handled in high vacuum, or under dry nitrogen or hydrogen.
	Merck Index, p. 359 (1968).
Carbon Dioxide	See DIETHYL MAGNESIUM plus Air.
Water	See DIETHYL MAGNESIUM plus Air.

DIETHYLPHOSPHINE $(C_2H_5)_2PH$

Air	Diethyl phosphine is spontaneously flammable in air.
	Von Schwartz, p. 323 (1918).

DIETHYL PEROXIDE $C_2H_5OOC_2H_5$

(self-reactive)	See OXYGEN plus Ethers.

DIETHYL PEROXYDICARBONATE $[C_2H_5OCOO-]_2$

(self-reactive)	Diethyl peroxydicarbonate decomposes rapidly at room temperature, sometimes with an explosion. It becomes hazardous above 10¡ C. One must avoid allowing it to crystallize.

Kirk and Othmer, Second Ed. **14:** 801, 803 (1963).

DIETHYL SULFATE $(C_2H_5O)_2SO_2$

Metals and Water	The presence of moisture in a metal container of diethyl sulfate caused formation of sulfuric acid which reacted with the metal to release hydrogen which pressurized and exploded the container.
	Chem. Abst. **28:** 2908 (1934).
	Angew. Chem. Intern. Ed. Engl. **47:** 105 (1934).
Potassium Tert.-Butoxide	See ACETONE plus Potassium Tert.-Butoxide.

DIETHYL TELLURIDE $(C_2H_5)_2Te$

Air	Diethyl telluride is spontaneously flammable in air.
	Ellern, pp. 24-25 (1968).

1,2-DIETHYLTETRAIODODIALUMINUM $C_2H_5I_2Al_2I_2C_2H_5$

Air	1,2-Diethyl tetraiodo dialuminum is spontaneously flammable in air.
	Douda (1966).

DIETHYLZINC $(C_2H_5)_2Zn$

Air	Diethyl zinc is spontaneously flammable in air.
	Douda (1966). *Handbook Chem. Phys.*, p. C-715 (1970-1971).
	Mellor **1:** 376 (1946-1947).
	See also CHLORINE plus Diethyl Zinc.
Chlorine	See CHLORINE plus Diethyl Zinc.
Hydrazine	See ZINC DIAMIDE plus Hydrazine.

Water — Diethyl zinc reacts violently with water.

Brauer (1965).

2,4-DIETHYNYL-5-METHOXYTOLUENE

$(CH{\equiv}C\text{-})_2C_6H_2(CH_3)OCH_3$

(self-reactive) — The polymer of this material explodes thermally.

Chem. Abst. **75:** 19831 (1971).

2,4-DIETHYNYL-5-METHYLPHENOL $(CH{=}C\text{-})_2C_6H_2(OH)CH_3$

(self-reactive) — This compound is unstable in light and air.

Chem. Abst. **75:** 19831 (1971).

DIFLUORAMINE NHF_2

(self-reactive) — A small flask of gaseous difluoramine in a train of glass apparatus broke loose and exploded when it fell to the concrete floor. A nearby glass U-tube containing liquid difluoramine at minus 80¡ C exploded either from the shock of the first explosion or from the inrush of air after the apparatus broke.

MCA Case History **768** (1961).

Difluoramine has a tendency to explode when in the solid state or during the process of freezing or melting.

Lawless and Smith, pp. 70-71 (1968).

Chlorine Dioxide — See CHLORINE DIOXIDE plus Difluoramine.

DIFLUORINE PEROXIDE O_2F_2

Organic Matter — Even at minus 160¡C or below a violent reaction or an explosion results when dioxygen difluoride reacts with any organic material and most inorganic materials containing hydrogen.

Solomon, Kacmarck, and McDonough, *J. Chem. Eng. Data* **13** (4): 529-531 (1968).

Sulfur Trioxide

The reaction of sulfur trioxide and oxygen difluoride is very vigorous and explosions occur if the reaction is carried out in the absence of a solvent.

Solomon, Kacmarck and McDonough, *J. Chem. Eng. Data* **13** (4): 529-531 (1968).

DIFLUORODIAZENE N_2F_2

(self-reactive)

Studies of the isomerization of difluorodiazine in a copper tube indicated that the cis form is much less stable than the trans.

Lawless and Smith, pp. 42, 43 (1968).

DIGERMANE Ge_2H_6

Air

Digermane ignites spontaneously in air.

Ellern, p. 22 (1968).

DIHYDRAZINOCUPRIC CHLORATE $Cu(H_2NNH_2)_2ClO_3$

(See CUPRIC-DIHYDRAZINE CHLORATE)

DIHYDRAZINOZINC CHLORATE $Zn(N_2H_4)_2(ClO_3)_2$

(self-reactive)

This compound detonates when struck.

Mellor **2, Supp. 1:** 592 (1956).

See ZINC-HYDRAZINE CHLORATE.

DIHYDROHEXABORANE

(See HEXABORANE (12))

1, 6-DIIODO-2,4-HEXADIYNE $(I•CH_2C≡C-)_2$

(self-reactive)	1, 6-diiodo-2,4-hexadiyne is shock-sensitive.
	P.E. Drieder and H.V. Isaacson, *Chem. Eng. News* **50** (12): 51 (1972).

DIIODOMETHANE ICH_2I

Sodium-Potassium Alloy	See SODIUM-POTASSIUM ALLOY plus Diiodomethane.

DIISOAMYL ZINC $((CH_3)_2CHC_2H_4)_2Zn$

Air	Isoamyl zinc is spontaneously flammable in air.
	Dangerous Chem. Code, p. 343 (1951).

DIISOBUTYL ALUMINUM CHLORIDE

(See CHLORODIISOBUTYL ALUMINUM)

DIISOBUTYLALUMINUM HYDRIDE $(C_4H_9)_2AlH$

Air	Diisobutyl aluminum hydride is spontaneously flammable in air.
	Rose (1961).

DIISOBUTYLENE $CH_2{=}C(CH_3)CH_2C(CH_3)_3$

Chorosulfonic Acid	Mixing diisobutylene and chlorosulfonic acid in a closed container caused the temperature and pressure to increase.
	Flynn and Rossow (1970). See Note under complete reference.
Oleum	Mixing diisobutylene and oleum in a closed container caused the temperature and pressure to increase.
	Flynn and Rossow (1970). See Note under complete

	reference.
Sulfuric Acid	Mixing diisobutylene and 96% sulfuric acid in a closed container caused the temperature and pressure to increase.
	Flynn and Rossow (1970). See Note under complete reference.

DIISOBUTYL ZINC $((CH_3)_2CHCH_2)_2Zn$

Air	Isobutyl zinc is spontaneously flammable in air.
	Dangerous Chem. Code, p. 343 (1951).

DIISOPROPYLBERYLLIUM $(C_3H_7)_2Be$

Water	Diisopropyl beryllium reacts explosively with water.
	G.E. Coates and F. Glockling, *J. Chem. Soc.* **106:** 22 (1954).

DIISOPROPYL ETHER $(CH_3)_2CHOCH(CH_3)_2$

Air	A flask of diisopropyl ether was being heated on a steam bath with gentle shaking when an explosion occurred. In a second instance, an explosion occurred after practically all the ether had been distilled.
	MCA Guide for Safety, Appendix 3 (1972).
	Diisopropyl ether and air form highly explosive peroxides.
	Wischmeyer (1969).
Air or Oxygen	See OXYGEN plus Ethers.
	See OXYGEN plus Isopropyl Ether.
Chlorosulfonic Acid	Mixing diisopropyl ether and chlorosulfonic acid in a closed container caused the temperature and pressure to increase.
	Flynn and Rossow (1970). See Note under complete reference.
Nitric Acid	Mixing diisopropyl ether and 70% nitric acid in a closed

	container caused the temperature and pressure to increase.
	Flynn and Rossow (1970). See Note under complete reference.

DIISOPROPYL PEROXYDICARBONATE $[(CH_3)_2CHOC(O)O-]_2$

(self-reactive)	Diisopropyl perdicarbonate decomposes rapidly at room temperature and sometimes explodes. It becomes hazardous above 10¡ C. It should not be allowed to crystallize.
	Kirk and Othmer, Second Ed. **14:** 801, 803 (1963).
Organic Matter	Upon contact with diisopropyl peroxydicarbonate, combustible organic materials can ignite or explode.
	Haz. Chem. Data p. 121 (1973).

DILITHIUM METHYLENE CH_2Li_2

(See METHYLENE DILITHIUM)

1,2-DIMETHOXYETHANE $CH_2(OCH_3)CH_2(OCH_3)$

Lithium Aluminum Hydride	See LITHIUM ALUMINUM HYDRIDE plus 1,2-Dimethoxyethane.

2,2-DIMETHOXYPROPANE $CH_3C(OCH_3)_2CH_3$

Manganese Perchlorate and Ethyl Alcohol	See ETHYL ALCOHOL plus Manganese Perchlorate and 2,2-Dimethoxypropane.
Nickel Perchlorate	See NICKEL PERCHLORATE plus 2,2-Dimethoxypropane.

DIMETHYLALLYLARSINE

(See ALLYLDIMETHYL ARSINE)

DIMETHYLAMINO CHLORODIBORANE

(See CHLORO (DIMETHYLAMINO) DIBORANE)

N, N-DIMETHYLANILINE $C_6H_5N(CH_3)_2$

Benzoyl Peroxide	See BENZOYL PEROXIDE plus N, N-Dimethylaniline.

DIMETHYLARSINE $(CH_3)_2AsH$

Air	Dimethylarsine is spontaneously flammable in air. *Douda* (1966). *Handbook Chem. Phys.,* p. C-681 (1970-1971).

DIMETHYLBENZYLCARBINOL

(See 2(X,Y-XYLYL)ETHANOL)

DIMETHYL CARBONATE $CH_3OCOOCH_3$

Potassium Tert.-Butoxide	See ACETONE plus Potassium Tert.-Butoxide.

DIMETHYL ETHER CH_3OCH_3

Aluminum Hydride	See ALUMINUM HYDRIDE plus Dimethyl Ether.
Lithium Aluminum Hydride	See LITHIUM ALUMINUM HYDRIDE plus Dimethyl Ether.

DIMETHYL FORMAMIDE $HCON(CH_3)_2$

Bromine	See BROMINE plus Dimethyl Formamide.
Carbon Tetrachloride	Dimethyl formamide and carbon tetrachloride react violently at temperatures above 65¡ C.

	Kittila, p. 165 (1967).
Chlorinated Hydrocarbons	Some halogenated hydrocarbons reacted with dimethyl formamide in the presence of iron at moderate temperatures.
	Kittila, p. 165 (1967).
Chromic Anhydride	See CHROMIC ANHYDRIDE plus Dimethyl Formamide.
2,5-Dimethylpyrrole and Phosphorus Oxychloride	See 2,5-DIMETHYLPYRROLE plus Phosphorus Oxychloride and Dimethyl Formamide.
Hexachlorobenzene	Dimethyl formamide and hexachlorobenzene react violently above 65¡ C.
	Kittila, p. 165 (1967).
Magnesium Nitrate	This mixture undergoes spontaneous decomposition. Nitrates of sodium, lithium, lead, copper and silver do not react under similar conditions.
	Kittila, p. 165 (1967).
Methylene Diisocyanate	Methylene diisocyanate polymerized violently on contact with dimethyl formamide.
	Kittila, p. 122 (1967).
Organic Nitrates	Dimethyl formamide undergoes spontaneous decomposition in the presence of organic nitrates.
	du Pont Prod. Inf. Bull., Dimethylformamide.
Phosphorus Trioxide	Dimethyl formamide, dimethyl sulfoxide, dimethyl sulfite, or methanol and phosphorus trioxide react very violently, often charring.
	Mellor **8, Supp. 3:** 382 (1971).
Triethyl Aluminum	Dimethyl formamide and triethyl aluminum form an explosive mixture when heated together.
	du Pont Prod. Inf. Bull., Dimethylformamide.

uns-DIMETHYLHYDRAZINE (UDMH)

$(CH_3)_2NNH_2$

Air	Unsymmetrical dimethyl hydrazine, when spread on a large surface, may ignite spontaneously.
	Def. Res. and Eng., pp. 299-300 (1963).
Hydrogen Peroxide	Spontaneous ignition of UDMH can occur on contact with oxidants like hydrogen peroxide and fuming nitric acid.
	Haz. Chem. Data (1966).
Nitric Acid	See NITRIC ACID plus Dimethylhydrazine.
Nitric Acid (Fuming)	See UNSYMMETRICAL DIMETHYL HYDRAZINE plus Hydrogen Peroxide.
Nitric Acid, Nitrogen Tetroxide, and Sulfuric Acid	Combinations of unsymmetrical dimethylhydrazine, aniline, or furfuryl alcohol as fuels with hydrogen peroxide or a mixture of nitric acid-nitrogen tetroxide-sulfuric acid as oxidizers ignite with little delay and are used as propellants.
	Chem. Abst. **51:** 3961d (1957); **63:** 4067h (1965).
	Brennstoff-Chem. **46** (4): 117-24 (1965).
Nitric Oxide	See NITRIC OXIDE plus Unsymmetrical Dimethylhydrazine.

DIMETHYLMAGNESIUM $(CH_3)_2Mg$

Air	Dimethyl magnesium is spontaneously flammable in air.
	Coates, p. 29 (1956).

DIMETHYL MALONATE $CH_2(COOCH_3)_2$

Methyl Azide	See METHYL AZIDE plus Dimethyl Malonate.

DIMETHYLMANGANESE $(CH_3)_2Mn$

Air	Dimethyl manganese is spontaneously flammable in air.
	Zeiss, p. 432 (1960).

2,5-DIMETHYLPYRROLE $(CH_3)_2C_4H_3N$

Phosphorus Oxychloride and Dimethyl Formamide	A complex of phosphorus oxychloride and dimethyl formamide was formed, then 2,5-dimethylpyrrole was added slowly. Internal temperature was 15¡ C. When only a part of the 2,5-dimethylpyrrole had been added the chemist noted that a vortex was no longer being formed by the stirrer. When he agitated the flask, the mixture erupted.
	MCA Case History **1460** (1968).

DIMETHYL SULFATE $(CH_3)_2SO_4$

Ammonium Hydroxide	See AMMONIUM HYDROXIDE plus Dimethyl Sulfate.
Sodium Azide	See SODIUM AZIDE plus Dimethyl Sulfate.

DIMETHYL SULFITE $SO_3(CH_3)_2$

Phosphorus Trioxide	See DIMETHYL FORMAMIDE plus Phosphorus Trioxide.

DIMETHYL SULFOXIDE $(CH_3)_2SO$

Acetyl Chloride	See DIMETHYL SULFOXIDE plus Acyl Halides.
Acyl Halides	Dimethyl sulfoxide decomposes violently on contact with a wide range of acyl halides, aryl halides and related compounds. Examples are phenyl and tolyl chloride, acetyl chloride, benzenesulfonyl chloride, benzoyl chloride, cyanuric chloride, phosphorus chloride, phosphorus oxychloride, and thionyl chloride. Dimethyl sulfoxide should be used with caution in exploratory reactions.

	Chem. Eng. News **35** (9): 87 (1957). *BCISC* **39** (154): 15 (1968). *Chem. Ind.* **40:** 1706-1707 (1967).
Benzenesulfonyl Chloride	See DIMETHYL SULFOXIDE plus Acyl Halides.
Benzoyl Chloride	See DIMETHYL SULFOXIDE plus Acyl Halides.
p-Bromobenzoyl Acetanilide	See p-BROMOBENZOYL ACETANILIDE plus Dimethyl Sulfoxide.
Cyanuric Chloride	See DIMETHYL SULFOXIDE plus Acyl Halides.
Iodine Pentafluoride	The reaction of dimethyl sulfoxide and iodine pentafluoride can be controlled to give a number of products, but the unmoderated reaction is quite violent because of the predominant formation of gaseous fluoromethanes and sulfuroxyfluorides as the temperature increases.
	E.M. Lawless, *Chem. Eng. News* **47** (12): 8, 109 (1969).
Magnesium Perchlorate	In the preparation of anhydrous dimethyl sulfoxide by vacuum distillation from anhydrous magnesium perchlorate, an explosion occurred.
	MCA Case History **1187** (1966). *Karasch* (1961). *Chem. Eng. News* **43** (37): 62 (1965).
Methyl Bromide	See METHYL BROMIDE plus Dimethyl Sulfoxide.
Perchloric Acid	An explosion occurs when 70% perchloric acid contacts sulfoxides.
	MCA Case History **1187** (1966). *Karasch* (1961).
	See also SULFOXIDES plus Perchloric Acid.
Periodic Acid	In periodic-dimethyl sulfoxide oxidizing systems, violent explosions can occur if the concentration of periodic acid is too strong. For example, in oxidizing glycopyranosides an explosion took place at a 1.5N concentration of the periodic acid.
	R. J. Yu and C. T. Bishop, *Can. J. Chem.* **45:** 2195 (1967). *Chem. Eng. News* **44** (15): 48 (1966). *J. Am. Chem. Soc.* **90** (7): 1924 (1968).
Phenyl Chloride	See DIMETHYL SULFOXIDE plus Acyl Halides.

Phosphorus Oxychloride	See DIMETHYL SULFOXIDE plus Acyl Halides.
Phosphorus Trichloride	See DIMETHYL SULFOXIDE plus Acyl Halides.
Phosphorus Trioxide	See DIMETHYL FORMAMIDE plus Phosphorus Trioxide.
Potassium Permanganate	A mixture of the two will flash instantaneously. *Ellern*, p. 50 (1968).
Silver Fluoride	Dimethyl sulfoxide is violently reactive with fluorinating agents such as silver fluoride. *Chem. Eng. News* **47** (12): 8, 109 (1969).
Sodium Hydride	The reaction of these two reagents to prepare methyl sulfinyl carbanion can cause explosions. *Chem. Eng. News* **44** (14): 48 (1966); **44** (24): **7** (1966).
Thionyl Chloride	See DIMETHYL SULFOXIDE plus Acyl Halides.
Tolyl Chloride	See DIMETHYL SULFOXIDE plus Acyl Halides.

DINITROANILINE HYDROCHLORIDE $(O_2N)_2C_6H_3NH_2{\bullet}HCl$

Nitrosylsulfuric Acid	See NITROSYLSULFURIC ACID plus Dinitroaniline Hydrochloride.

2,4-DINITROBENZENE SULFENYL CHLORIDE $(NO_2)_2C_6H_3SCl$

(self-reactive)	An explosion may occur when the solvent symmetrical tetrachlorethane is almost removed in the chlorinolysis of 2,4-dinitrophenyl disulfide. *MCA Guide for Safety*, Appendix 3 (1972).

2,4-DINITROCHLOROBENZENE $(O_2N)_2C_6H_3Cl$

(self-reactive)	B. D. Halpern, *Chem. and Eng. News*, **29:** 2666 (1951).

DINITROGEN PENTOXIDE O_2NONO_2

Ozone	See OZONE plus Dinitrogen Pentoxide.

2,4-DINITROPHENYL DISULFIDE $[(O_2N)_2C_6H_3S\text{-}]_2$

Tetrachlorethane	See 2, 4-DINITROBENZENE SULFENYL-CHLORIDE (self-reactive).

DINITROSOPENTAMETHYLENETETRAMINE $(ON)_2(CH_2)_5N_4$

(self-reactive)	This chemical is a blowing agent with an exothermic decomposition slightly above its melting point of 203¡C. *Ellern,* p. 161 (1968).

DIOXANE

Hydrogen and	See HYDROGEN plus Dioxane and Nickel
Nickel (Raney)	(Raney).
Silver Perchlorate	See SILVER PERCHLORATE plus Toluene.

DIOXYGEN DIFLUORIDE

(See DIFLUORINE PEROXIDE)

DIPEROXYTEREPHTHALIC ACID $(HOOOC)_2C_6H_4$

(self-reactive)	This acid explodes under the influence of a shock or an increase in temperature. *Chem. Reviews* **45:** 14, 15 (1949).

DIPHENYLAMINE $(C_6H_5)_2NH$

Hexachloromelamine	See HEXACHLOROMELAMINE plus Organic Contaminants.
Trichloromelamine	See HEXACHLOROMELAMINE plus Organic Contaminants.

DIPHENYL DIAZOSULFIDE $(C_6H_5N_2)_2S$

Air	Phenyldiazosulfide explodes when air-dried.
	Chem. Eng. News **29:** 5473 (1951).

1,2-DIPHENYLETHYLENE $C_6H_5CH{=}CHC_6H_5$

Oxygen	See OXYGEN plus Diphenylethylene.

DIPHENYLTETRACETYLENE $(C_6H_5C{=}CC{=}C)_2$

(self-reactive)	Diphenyltetracetylene was stable for at least 13 months at room temperature in the dark. When placed on a metallic plate, it decomposed explosively with much soot.
	Chem. Abst. **45:** 7082 (1962).

DIPHOSPHINE H_2PPH_2

Air	The liquid is spontaneously flammable in air and the presence of a trace of the vapor makes phosphine and other combustible gases spontaneously flammable in air.
	Mellor **8:** 829 (1946-1947).
	Mellor **1:** 376 (1946-1947).
	Mellor **8, Supp. 3:** 273 (1971).

DIPHOSPHORYL CHLORIDE $P_2O_3Cl_2$

Water	The vigorous hydrolysis of pyrophosphoryl chloride is like that of phosphorus pentoxide.
	Mellor **8, Supp. 3:** 505.

DIPOTASSIUM NITROACETATE

(See POTASSIUM ACI-NITROACETATE)

DIPROPARGYL ETHER $(CH{=}CCH_2)_2O$

Air	An explosion occurred in a 50-gallon stainless steel still during the distillation of dipropargyl ether.
	MCA Guide for Safety, Appendix 3 (1972).

DIPROPYLALUMINUM HYDRIDE $(C_3H_7)_2AlH$

Air	Di-n-propylaluminum hydride ignites spontaneously in air.
	Aluminum Alkyls, p. 21. *Fire Haz. Prop.* (1969).
Water	Di-n-propylaluminum hydride reacts violently with water.
	Aluminum Alkyls, p. 21.

DIPROPYLCHLOROBORINE

(See CHLORODIPROPYLBORANE)

DIPROPYLZINC $(C_3H_7)_2Zn$

Air	Di-n-propyl zinc is spontaneously flammable in air.
	Douda (1966).

DISILANE (SILICOETHANE) Si_2H_6

Air	See OXYGEN plus Disilane.
Carbon Tetrachloride	Disilane explodes violently when mixed with carbon

	tetrachloride; reacts vigorously with incandescence in contact with chloroform.
	Mellor **6:** 223 (1946-1947).
Chloroform	See DISILANE plus Carbon Tetrachloride.
Oxygen	See OXYGEN plus Disilane.
Sulfur Hexafluoride	Disilane explodes violently in contact with sulfur hexafluoride.
	Mellor **6:** 223 (1946-1947).

DISILOXANE $(SiH_3)_2O$

Air	See SILANES plus Air.

(DISILYLAMINO) DIBORANE $B_2H_5N(SiH_3)_2$

Air	Disilylamino diborane is spontaneously flammable in air.
	Douda (1966).

DISILYLAMINO DICHLOROBORINE

(See DICHLORO(DISILYLAMINO)BORANE)

DISODIUM NITRITE Na_2NO_2

(self-reactive)	See POTASSIUM plus Sodium Nitrite and Ammonia.

DISULFUR DINITRIDE

(See SULFUR NITRIDE)

DISULFURYL AZIDE $(N_3SO_2)_2O$

(self-reactive)	Pyrosulfuryl azide decomposes explosively below 80¡C.

Mellor **8, Supp. 2:** 36 (1967).

DIVANADIUM DODECACARBONYL $V_2(CO)_{12}$

Air	Divanadium dodecacarbonyl is spontaneously flammable in air.
	R. L. Pruett and J. E. Wyman, *Chem. and Ind.* **9** (1): 119-120 (1960).

DIVINYL ACETYLENE

(See 1,5-HEXADIEN-3-YNE)

DIVINYL ETHER $(CH_2{=}CH)_2O$

Air	See OXYGEN plus Ethers.
Oxygen	See OXYGEN plus Ethers.

DIVINYLZINC$(CH_2{=}CH)_2Zn$

Air	Divinyl zinc is spontaneously flammable in air.
	Zeiss (1960).

DOWICIL 100 [1-(3-CHLOROALLYL)-3,5,7-TRIAZO-1-

AZONIAADAMANTANE CHLORIDE]

$C_6H_{12}N_4$-$(CH_2CHCHCl)Cl$

Hydrogen Chloride	This compound is stable below 120¡C if kept dry and away from hydrogen chloride. Both water and hydrogen chloride will cause chemical decomposition. Decomposition is immediate with hydrogen chloride; it is somewhat slower in water.
	Dowicil
Water	See DOWICIL 100 plus Hydrogen Chloride.

DYSPROSIUM Dy

Air	See RARE EARTH METALS plus Air.
Halogens	See RARE EARTH METALS plus Halogens.

ENDRIN $C_{12}H_8OCl_6$

Parathion	See PARATHION plus Endrin.

EPICHLOROHYDRIN

2-Aminoethanol	See 2-AMINOETHANOL plus Epichlorohydrin.
Chlorosulfonic Acid	Mixing epichlorohydrin and 2-aminoethanol in a closed container caused the temperature and pressure to increase. *Flynn and Rossow* (1970). See Note under complete reference.
Ethylene Diamine	See ETHYLENE DIAMINE plus Epichlorohydrin.
Ethyleneimine	Mixing epichlorohydrin and ethyleneimine in a closed container caused the temperature and pressure to increase. *Flynn and Rossow* (1970). See Note under complete reference.
Nitric Acid	Mixing epichlorohydrin and 70% nitric acid in a closed container caused the temperature and pressure to increase. *Flynn and Rossow* (1970). See Note under complete reference.
Oleum	Mixing epichlorohydrin and oleum in a closed container caused the temperature and pressure to increase. *Flynn and Rossow* (1970). See Note under complete reference.

Potassium Tert.-Butoxide	See ACETONE plus Potassium Tert.-Butoxide.
Sulfuric Acid	See ETHYLENE CYANOHYDRIN plus Sulfuric Acid.
	Mixing epichlorohydrin and 96% sulfuric acid in a closed container caused the temperature and pressure to increase.
	Flynn and Rossow (1970). See Note under complete reference.

ERBIUM Er

Air	See RARE EARTH METALS plus Air.
Halogens	See RARE EARTH METALS plus Halogens.

ERBIUM PERCHLORATE $Er(ClO_4)_3$

Acetonitrile	See ACETONITRILE plus Erbium Perchlorate.

ESTERS

Nitrates	See NITRATES plus Esters.

ETHANE C_2H_6

Chlorine	See CHLORINE plus Ethane.
Chlorine Dioxide	See CHLORINE DIOXIDE plus Butadiene.

1,2-ETHANETHIOL $HSCH_2CH_2SH$

Calcium Hypochlorite	See CALCIUM HYPOCHLORITE plus 1-Propanethiol.

ETHERS

(See also specific ethers)

Air or Oxygen	Peroxides form on standing and are very dangerous.

	Bahme, p. 46 (1961).
Boron Triiodide	See BORON TRIIODIDE plus Ethers.

ETHOXYACETYLENE $C_2H_5OC{\equiv}CH$

Ethylmagnesium Iodide	See ETHYLMAGNESIUM IODIDE plus Ethoxyacetylene.

(4-ETHOXYBUTYL) DIETHYLALUMINUM $(C_2H_5)_2Al(CH_2)_4OC_2H_5$

Air	Diethyl-4-ethoxybutylamine is spontaneously flammable in air. *Douda* (1966).

2-(2-ETHOXYETHOXY)ETHYL ACETATE $CH_3COOCH_2CH_2OCH_2CH_2OC_2H_5$

Chlorosulfonic Acid	Mixing ethyl glycol monoethyl ether acetate and chlorosulfonic acid in a closed container caused the temperature and pressure to increase. *Flynn and Rossow* (1970). See Note under complete reference.
Oleum	Mixing ethylene glycol monoethyl ether acetate and oleum in a closed container caused the temperature and pressure to increase. *Flynn and Rossow* (1970). See Note under complete reference.

ETHOXYETHYNYLCARBINOL $C_2H_5OCHOHC{\equiv}CH$

(self-reactive)	Violent explosions have been recorded in the use of this material. *Rutledge*, p. 35 (1968).

ETHOXYTRIETHYLDIPHOSPHINYL OXIDE

$(C_2H_5)_2POP(C_2H_5)(OC_2H_5)$

Air	Triethyl ethoxy diphosphinyl oxide is spontaneously flammable in air. *Kaufman* (1961).

ETHYL ACETATE $C_2H_5COOCH_3$

Chlorosulfonic Acid	Mixing ethyl acetate and chlorosulfonic acid in a closed container caused the temperature and pressure to increase. *Flynn and Rossow* (1970). See Note under complete reference.
Lithium Aluminum Hydride and 2-Chloromethylfuran	See 2-CHLOROMETHYLFURAN plus Lithium Aluminum Hydride and Ethyl Acetate.
Oleum	Mixing ethylacetate and oleum in a closed container caused the temperature and pressure to increase. *Flynn and Rossow* (1970). See Note under complete reference.
Potassium Tert.-Butoxide	See ACETONE plus Potassium Tert.-Butoxide.

ETHYL ACETOACETATE $C_2H_5OCOCH_2COCH_3$

Tribromoneopentyl Alcohol and Zinc	Tribromoneopentyl alcohol, ethyl acetoacetate and zinc were being reacted to prepare the zinc chelate of tribromoneopentyl acetoacetate. When the reaction had proceeded to where 80% of the by-product ethanol had been removed, a violent decomposition occurred. *Wischmeyer* (1972). *U.S. Pat.* 3,578,619 (1971).

ETHYL ACRYLATE $C_2H_5OCOCH{=}CH_2$

Chlorosulfonic Acid	Mixing ethyl acrylate and chlorosulfonic acid in a closed container caused the temperature and pressure to increase. *Flynn and Rossow* (1970). See Note under complete reference.

ETHYL ALCOHOL CH_3CH_2OH

Acetyl Chloride	See ACETYL CHLORIDE plus Ethyl Alcohol.
Ammonium Hydroxide and Silver Oxide	See SILVER OXIDE plus Aqueous Ammonia and Ethyl Alcohol.
Bromine Pentafluoride	See BROMINE PENTAFLUORIDE plus Acetic Acid.
Calcium Hypochlorite	See CALCIUM HYPOCHLORITE plus Ethyl Alcohol.
Chlorine Trioxide	See CHLORINE TRIOXIDE plus Alcohol.
Chromic Anhydride	See CHROMIC ANHYDRIDE plus Ethyl Alcohol.
Chromyl Chloride	See CHROMYL CHLORIDE plus Ammonia.
Cyanuric Acid	See CYANURIC ACID plus Water.
Hydrogen Peroxide	The addition of alcohols to highly concentrated hydrogen peroxide forms powerful explosives which can be detonated by shock. *Bahme,* p. 9 (1961).
Hydrogen Peroxide and Sulfuric Acid	See ALCOHOLS plus Hydrogen Peroxide and Sulfuric Acid.
Iodine, Methyl Alcohol, and Mercuric Oxide	See IODINE plus Ethyl Alcohol, Methyl Alcohol, and Mercuric Oxide.
Manganese Perchlorate and 2,2-Dimethoxypropane	A violent explosion occurred when manganese perchlorate, absolute alcohol and 2,2-dimethoxypropane were gently refluxed for about two hours under a stream of nitrogen. *Chem. Eng. News* **48** (28): 6 (July 6, 1970).

Mercuric Nitrate	See MERCURIC NITRATE plus Ethyl Alcohol.
Nitric Acid	See NITRIC ACID plus Ethyl Alcohol.
Perchlorates	See PERCHLORATES plus Benzene.
Perchloric Acid	See PERCHLORIC ACID plus Ethyl Alcohol.
Permanganates and Sulfuric Acid	See PERMANGANATES plus SULFURIC Acid and Benzene.
Permanganic Acid	See PERMANGANIC ACID plus Ethyl Alcohol.
Potassium Superoxide	See POTASSIUM SUPEROXIDE plus Ethyl Alcohol.
Potassium Tert.-Butoxide	See ACETONE plus Potassium Tert.-Butoxide.
Silver and Nitric Acid	See SILVER plus Ethyl Alcohol and Nitric Acid.
Silver Nitrate	See SILVER NITRATE plus Ethyl Alcohol.
Silver Perchlorate	See SILVER PERCHLORATE plus Benzene.
Sodium Hydrazide	See SODIUM HYDRAZIDE plus Air.
Uranyl Perchlorate	See URANYL PERCHLORATE plus Ethyl Alcohol.

ETHYL ALUMINUM DICHLORIDE

(See DICHLOROETHYLALUMINUM)

ETHYL ALUMINUM SESQUICHLORIDE

(See TRICHLOROTRIETHYLDIALUMINUM)

m-ETHYLANILINE $C_2H_5C_6H_4NH_2$

Nitric Acid	See NITRIC ACID plus m-Ethylaniline.

ETHYL AZIDES

(self-reactive)	See METHYL AZIDES (self-reactive).

ETHYL BORON DICHLORIDE

(See DICHLOROETHYLBORANE)

ETHYLENE $CH_2=CH_2$

Aluminum Chloride	See ALUMINUM CHLORIDE plus Ethylene.
Benzoyl Peroxide and Carbon Tetrachloride	See BENZOYL PEROXIDE plus Carbon Tetrachloride and Ethylene.
Bromotrichloromethane	See BROMOTRICHLOROMETHANE plus Ethylene.
Carbon Tetrachloride	See CARBON TETRACHLORIDE plus Ethylene.
Chlorine	See CHLORINE plus Ethylene.
Chlorine Dioxide	See CHLORINE DIOXIDE plus Butadiene.
Nitrogen Dioxide	See NITROGEN TETROXIDE plus Olefins.
Nitromethane and Aluminum Chloride	A mixture of ethylene with nitromethane-aluminum chloride catalyst in an autoclave exploded at a temperature below 40¡C. F. M. Cowen and O. Rorso, *Chem. Eng. News* **26:** 2257 (1948). See also ALUMINUM CHLORIDE plus Nitromethane and Organic Matter.
Ozone	See OZONE plus Ethylene.

ETHYLENE CYANOHYDRIN

(See 2-CYANOETHANOL)

ETHYLENEDIAMINE $H_2NCH_2CH_2NH_2$

Acetic Acid	See ACETIC ACID plus Ethylene Diamine.

Acetic Anhydride	See ACETIC ANHYDRIDE plus Ethylene Diamine.
Acrolein	See ACROLEIN plus Ethylene Diamine.
Acrylic Acid	See ACRYLIC ACID plus Ethylene Diamine.
Acrylonitrile	See ACRYLONITRILE plus Ethylene Diamine.
Allyl Chloride	See ALLYL CHLORIDE plus Ethylene Diamine.
Carbon Disulfide	See CARBON DISULFIDE plus Ethylene Diamine.
Chlorosulfonic Acid	Mixing ethylene diamine and chlorosulfonic acid in a closed container caused the temperature and pressure to increase. *Flynn and Rossow* (1970). See Note under complete reference.
Epichlorohydrin	Mixing ethylene diamine and epichlorohydrin in a closed container caused the temperature and pressure to increase. *Flynn and Rossow* (1970). See Note under complete reference.
Ethylene Chlorohydrin	See ETHYLENE CHLOROHYDRIN plus Ethylene Diamine.
Hydrochloric Acid	Mixing ethylene diamine and 36% hydrochloric acid in a closed container caused the temperature and pressure to increase. *Flynn and Rossow* (1970). See Note under complete reference.
Mesityl Oxide	See MESITYL OXIDE plus Ethylene Diamine.
Nitric Acid	Mixing ethylene diamine and 70% nitric acid in a closed container caused the temperature and pressure to increase. *Flynn and Rossow* (1970). See Note under complete reference.
Oleum	Mixing ethylene diamine and oleum in a closed container caused the temperature and pressure to increase. *Flynn and Rossow* (1970). See Note under complete reference.
Propiolactone (beta-)	Mixing ethylene diamine and propiolactone (beta-) in a closed container caused the temperature and pressure to

	increase.
	Flynn and Rossow (1970). See Note under complete reference.
Silver Perchlorate	See SILVER PERCHLORATE plus Ethylenediamine.
Sulfuric Acid	Mixing ethylene diamine and 96% sulfuric acid in a closed container caused the temperature and pressure to increase.
	Flynn and Rossow (1970). See Note under complete reference.
Vinyl Acetate	Mixing ethylene diamine and vinyl acetate in a closed container caused the temperature and pressure to increase.
	Flynn and Rossow (1970). See Note under complete reference.

ETHYLENEDIAMINE DIPERCHLORATE

$NH_2CH_2CH_2NH_2(ClO_4)_2$

(self-reactive)	This compound is an explosive that exceeds the power and brisance of TNT.
	ACS **146:**206. *Chem. Reviews* **44:**419-45 (1949).

ETHYLENE DICHLORIDE $ClCH_2CH_2Cl$

(See also 1,2-DICHLOROETHANE)

Ammonia	See AMMONIA plus Ethylene Dichloride.
Dimethyl Amino Propyl Amine	A tank of dimethyl amino propyl amine exploded violently when it reacted with wet ethylene dichloride which had been the tank's previous contents. Investigation revealed that this combination can be extremely hazardous.
	Doyle (1973).

ETHYLENE DIOXYAMINE PERCHLORATE

$CH_2CH_2ONHOHClO_4$

(self-reactive) | An explosion occurred in a laboratory during synthesis of ethylene dioxyamine perchlorate. It is believed that during some stage of purification of the material a low order explosion occurred.

BCISC **41** (162): 18 (April-June 1970).

ETHYLENE GLYCOL HOC_2H_4OH

Chlorosulfonic Acid | Mixing ethylene glycol and chlorosulfonic acid in a closed container caused the temperature and pressure to increase.

Flynn and Rossow (1970). See Note under complete reference.

Oleum | Mixing ethylene glycol and oleum in a closed container caused the temperature and pressure to increase.

Flynn and Rossow (1970). See Note under complete reference.

Sulfuric Acid | Mixing ethylene glycol and 96% sulfuric acid in a closed container caused the temperature and pressure to increase.

Flynn and Rossow (1970). See Note under complete reference.

ETHYLENE GLYCOL MONOMETHYL ETHER

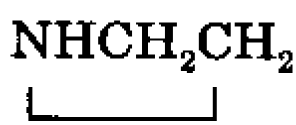
(See 2-METHOXYETHANOL)

ETHYLENE OXIDE $(CH_2)_2O$

Acids and Bases | Alkali metal hydroxides; acids; anhydrous chlorides of iron, tin, and aluminum; pure oxides of iron and aluminum; and metallic potassium are some of the catalysts that may cause liquid ethylene oxide to rearrange and/or polymerize, liberating heat.

	L. G. Hess and V. V. Tilton, *Ind. Eng. Chem.* **42:** 1251-8 (1950). A. K. Gupta, *J. Soc. Chem. Ind.* **68:** 179-83 (1949).
Alcohols	Explosions occur, although infrequently, from the combination of ethylene oxide and alcohols or mercaptans.
	Chem. Eng. News **20:** 1318 (1942).
Aluminum Chloride	See ETHYLENE OXIDE plus Acids and Bases. See ETHYLENE OXIDES plus Aluminum Oxide.
Aluminum Oxide	Ethylene oxide may polymerize violently when in contact with highly catalytic surfaces such as anhydrous chlorides of iron, tin and aluminum, or the pure oxides of aluminum and iron.
	Hazardous Chemicals Data (1966).
	See also ETHYLENE OXIDE plus Acids and Bases.
Ammonia	See AMMONIA plus Ethylene Oxide.
Copper	See COPPER plus Ethylene Oxide.
Iron Chlorides	See ETHYLENE OXIDE plus Acids and Bases. See ETHYLENE OXIDE plus Aluminum Oxide.
Iron Oxides	See ETHYLENE OXIDE plus Acids and Bases. See ETHYLENE OXIDE plus Aluminum Oxide.
Magnesium Perchlorate	See MAGNESIUM PERCHLORATE plus Ethylene Oxide.
Mercaptans	See ETHYLENE OXIDE plus Alcohols.
Potassium	See POTASSIUM plus Ethylene Oxide. See ETHYLENE OXIDE plus Acids and Bases.
Tin Chlorides	See ETHYLENE OXIDE plus Acids and Bases. See ETHYLENE OXIDE plus Aluminum Oxide.

ETHYLENEIMINE



(self-reactive)	Undiluted ethyleneimine can polymerize violently in the

	presence of acids or acid-forming materials.
	Ethyleneimine.
Acetic Acid	See ACETIC ACID plus Ethyleneimine.
Acetic Anhydride	See ACETIC ANHYDRIDE plus Ethyleneimine.
Acrolein	See ACROLEIN plus Ethyleneimine.
Acrylic Acid	See ACRYLIC ACID plus Ethyleneimine.
Allyl Chloride	See ALLYL CHLORIDE plus Ethyleneimine.
Carbon Disulfide	See CARBON DISULFIDE plus Ethyleneimine.
Chlorine	See CHLORINE plus Ethyleneimine.
Chlorosulfonic Acid	Mixing ethyleneimine and chlorosulfonic acid in a closed container caused the temperature and pressure to increase.
	Flynn and Rossow (1970). See Note under complete reference.
Epichlorohydrin	See EPICHLOROHYDRIN plus Ethyleneimine.
Glyoxal	See GLYOXAL plus Ethyleneimine.
Hydrochloric Acid	Mixing ethyleneimine and 36% hydrochloric acid in a closed container caused the temperature and pressure to increase.
	Flynn and Rossow (1970). See Note under complete reference.
Hydrofluoric Acid	Mixing ethyleneimine and 48.7% hydrofluoric acid in a closed container caused the temperature and pressure to increase.
	Flynn and Rossow (1970). See Note under complete reference.
Nitric Acid	Mixing ethyleneimine and 70% nitric acid in a closed container caused the temperature and pressure to increase.
	Flynn and Rossow (1970). See Note under complete reference.
Oleum	See OLEUM plus Ethyleneimine.
Propiolactone (beta-)	Mixing ethyleneimine and propiolactone (beta-) in a closed

	container caused the temperature and pressure to increase.
	Flynn and Rossow (1970). See Note under complete reference.
Silver	See SILVER plus Ethyleneimine.
Sodium Hypochlorite	Chlorination of ethyleneimine with sodium hypochlorite gives the explosive compound, 1-chloroethyleneimine.
	A.F. Graefe and R.E. Meyer, J. *Am. Chem. Soc.* **80:** 3939 (1958).
Sulfuric Acid	Mixing ethyleneimine and 96% sulfuric acid in a closed container caused the temperature and pressure to increase.
	Flynn and Rossow (1970). See Note under complete reference.
Vinyl Acetate	See VINYL ACETATE plus Ethyleneimine.

2-ETHYLHEXANAL $CH_3(CH_2)_3CH(C_2H_5)CHO$

Air	2-Ethylhexaldehyde is spontaneously flammable in air.
	A.B. Steele and J. Duggan, *Chem. Eng.* **66:** 160 (April 20, 1969).

ETHYL HYPOCHLORITE CH_3CH_2OCl

(self-reactive)	Ethyl hypochlorite decomposes explosively when exposed to light and rapidly even in its absence.
	Mellor **2, Supp. 1:** 560 (1956).
	See also ALCOHOLS plus Hypochlorous Acid.

ETHYLIODOMETHYLARSINE $(CH_3)(C_2H_5)AsI$

Air	Methyl ethyliodoarsine occasionally ignites spontaneously in air.
	ACS **15** (1923).

ETHYL ISONITRILE

(See ISOCYANOETHANE)

S-ETHYLISOTHIOUREA SULFATE $NH_2C(NH)SC_2H_5 \bullet H_2SO_4$

Chlorine	See CHLORINE plus S-Ethyl Isothiourea Sulfate.

ETHYLLITHIUM C_2H_5Li

Air	Ethyl lithium is spontaneously flammable in air. *Ellern* (1961).

ETHYLMAGNESIUM IODIDE C_2H_5MgI

Ethoxyacetylene	A laboratory scale-up of this reaction had failed to yield the desired Grignard end-product. After one hour, the reaction vessel exploded. *Chem. Eng. News* **44** (8): 40 (1966).

ETHYLMETHYLARSINE $HAs(CH_3)(C_2H_5)$

Air	Ethylmethylarsine is spontaneously flammable in air. *Ellern*, pp. 24-25 (1968).

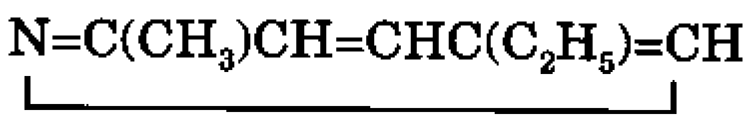
ETHYL METHYL ETHER $CH_3OC_2H_5$

Air	See OXYGEN plus Ethers.
Lithium Aluminum Hydride	See LITHIUM ALUMINUM HYDRIDE plus Dimethyl Ether.
Oxygen	See OXYGEN plus Ethers.

ETHYL METHYL KETONE $CH_3COC_2H_5$

Chlorosulfonic Acid	Mixing methyl ethyl ketone and chlorosulfonic acid in a closed container caused the temperature and pressure to increase.
	Flynn and Rossow (1970). See Note under complete reference.
Oleum	Mixing methyl ethyl ketone and oleum in a closed container caused the temperature and pressure to increase.
	Flynn and Rossow (1970). See Note under complete reference.
Potassium Tert.-Butoxide	See ACETONE plus Potassium Tert.-Butoxide.

5-ETHYL-2-METHYLPYRIDINE



Nitric Acid	See NITRIC ACID plus 2-Methyl-5-Ethylpyridine.
	See NITRIC ACID plus 5-Ethyl-2-Methyl Pyridine.

ETHYL NITRITE C_2H_5ONO

(self-reactive)	The decomposition of ethyl nitrite above 194¡F can be violently explosive.
	Chem. Haz. Data (1969).

ETHYL PERCHLORATE $C_2H_5ClO_4$

(self-reactive)	This compound is an explosive that exceeds the power and brisance of TNT.
	*ACS **146:** 296. Chem. Reviews* **44:** 419-45 (1949).

ETHYLPHOSPHINE $C_2H_5PH_2$

Bromine	See BROMINE plus Ethyl Phosphine.
Chlorine	See BROMINE plus Ethyl Phosphine.
Nitric Acid	See BROMINE plus Ethyl Phosphine.

5-ETHYL-2-PICOLINE $C_8H_{11}N$

Nitric Acid	This reaction results in the formation of 5-(1,1 dinitroethyl)-2-picoline, an explosive compound. In addition, the reaction itself is potentially violent, especially in closed systems.
	H. Rubenstein, G. Hazen, and R. Zerfing, *Chem. Eng. Data* **12:** 149-50 (1967).

ETHYL SODIO-ACETOACETATE $C_2H_5OCOCH{=}CO(Na)CH_3$

2-Iodo-3, 5-Dinitrobiphenyl	See 2-IODO-3, 5-DINITROBIPHENYL plus Ethyl Sodio-Acetoacetate.

ETHYLSODIUM C_2H_5Na

Air	Ethyl sodium is spontaneously flammable in air.
	Douda (1966).

ETHYLTRICHLOROSILANE

(See TRICHLOROETHYLSILANE)

EUROPIUM

Air	See RARE EARTH METALS plus Air.
Halogens	See RARE EARTH METALS plus Halogens.

FERRIC BROMIDE $FeBr_3$

Potassium	See POTASSIUM plus Boron Tribromide.
Sodium	See SODIUM plus Cobaltous Bromide.

FERRIC CHLORIDE $FeCl_3$

Allyl Chloride	See SULFURIC ACID plus Allyl Chloride.
Potassium	See POTASSIUM plus Boron Tribromide.
Sodium	See SODIUM plus Cobaltous Bromide.

FERRIC FERROCYANIDE $Fe_4[Fe(CN)_6]_3$

Lead Chromate	See LEAD CHROMATE plus Ferric Ferrocyanide.

FERRIC HYPOPHOSPHITE $Fe(PH_2O_2)_3$

(self-reactive)	Ferric hypophosphite forms impact-sensitive ammunition-priming mixtures. *Mellor* **8, Supp. 3:** 623 (1971).

FERRIC OXIDE Fe_2O_3

Aluminum	See ALUMINUM plus Iron Oxide.
Calcium Hypochlorite	See CALCIUM HYPOCHLORITE plus Lead Oxide.
Cesium Carbide	See CESIUM CARBIDE plus Ferric Oxide.
Ethylene Oxide	See ETHYLENE OXIDE plus Acids and Bases. See ETHYLENE OXIDE plus Aluminum Oxide.

FERRIC OXIDE (HYDRATED) $Fe_2O_3XH_2O$

Hydrogen Sulfide	See HYDROGEN SULFIDE plus Hydrated Iron Oxide.

FERROCENE $(C_5H_5)_2Fe$

Ammonium Perchlorate	See AMMONIUM PERCHLORATE plus Dicyclopentadienyliron.

FERROUS BROMIDE $FeBr_2$

Potassium	See POTASSIUM plus Boron Tribromide.
Sodium	See SODIUM plus Cobaltous Bromide.

FERROUS CHLORIDE $FeCl_2$

Ethylene Oxide	See ETHYLENE OXIDE plus Acids and Bases.
	See ETHYLENE OXIDE plus Aluminum Oxide.
Potassium	See POTASSIUM Plus Boron Tribromide.
Sodium	See SODIUM plus Ferrous Chloride.

FERROUS IODIDE FeI_2

Potassium	See POTASSIUM plus Boron Tribromide.
Sodium	See SODIUM plus Cobaltous Bromide.

FERROUS OXIDE FeO

Air	Ferrous oxide is spontaneously flammable in air.
	Chem. Abst. **45:** 3276i (1951).
Ethylene Oxide	See ETHYLENE OXIDE plus Acids and Bases. See ETHYLENE OXIDE plus Aluminum Oxide.
Fluorine	See FLUORINE plus Ferrous Oxide.
Nitric Acid	When pyrophoric iron oxide is gently warmed with nitric acid, the oxide becomes incandescent.
	Mellor **13:** 716 (1946-1947).
Sulfur Dioxide	When ferrous oxide, prepared at 300¡C., is heated in sulfur dioxide, the mass becomes incandescent.

Mellor **13:** 715 (1946-1947).

FERROUS SULFIDE FeS

Air	Moist ferrous sulfide readily oxidizes in air and the heat evolved may cause incandescence. When ground in a mortar, the mass becomes incandescent.
	Mellor **14:** 157 (1946-1947).
Hydrogen Peroxide	See ANTIMONY TRISULFIDE plus Hydrogen Peroxide.
Lithium	See LITHIUM plus Ferrous Sulfide.

FLUORAZIDE N_3F

(self-reactive)	See FLUORINE AZIDE (self-reactive).

FLUORINE F_2

Acetaldehyde	See BROMINE plus Acetaldehyde.
Acetylene	Acetylene and fluorine will react violently.
	Chem. Safety Data Sheet **SD-7** (1957).
Acrylonitrile-Butadiene	See FLUORINE plus Solid Nonmetals and
Copolymer	Oxygen.
Alkali Oxides	The oxides of the alkalies and alkaline earths are vigorously attacked by fluorine gas with incandescence.
	Mellor **2:** 13 (1946-1947).
Alkaline Earth Oxides	See FLUORINE plus Alkali Oxides.
Alkenes	Fluorine causes unsaturated hydrocarbons to ignite spontaneously.
	Mellor **2, Supp. 1:** 55 (1956).
Alkylbenzenes	Fluorine causes aromatic hydrocarbons to ignite spontaneously.
	Mellor **2, Supp. 1:** 55 (1956).

Aluminum	See FLUORINE plus Metals.
Ammonia	Fluorine and ammonia burst into flame.
	Mellor **1:** 12; **8:** 216 (1946-1947).
	Mellor **8, Supp. 2:** 329 (1964).
Ammonium Hydroxide	Combination of fluorine and ammonium hydroxide results in flames and explosion.
	Mellor **2, Supp. 1:** 56 (1956).
Antimony	See ANTIMONY plus Bromine.
Antimony Trisulfide	The reaction at ordinary temperatures between fluorine and antimony trisulfide is accompanied by a blue flame.
	Mellor **9:** 522 (1946-1947).
Arsenic	Fluorine vigorously reacts with arsenic at ordinary temperatures.
	Mellor **9:** 34 (1946-1947).
Arsenic Trioxide	Fluorine reacts violently with arsenic trioxide.
	Mellor **9:** 101 (1946-1947).
Asphalt	See FLUORINE plus Common Materials and Oxygen.
Bakelite□	See FLUORINE plus Solid Nonmetals.
Boron	See BORON plus Fluorine.
Bromides	See FLUORINE plus Chlorides.
Bromine	Bromine unites with fluorine at ordinary temperatures with a luminous flame, forming bromine trifluoride.
	Mellor **2:** (1946-1947).
Buna N	See FLUORINE plus Solid Nonmetals and Oxygen.
Calcium	See CALCIUM plus Fluorine.
Calcium Carbonate	See FLUORINE plus Carbonates.
Calcium Oxide	Even when cold, fluorine will attack calcium oxide, evolving much heat and some light.
	Mellor **3:** 663 (1946-1947).

Calcium Silicide	Calcium silicide burns readily in fluorine. *Mellor* **6:** 169 (1946-1947).
Carbon	Graphitic or crystallized carbon tends to react explosively with fluorine after an intermediate induction period in a manner similar to that of ice. *NASA SP*-**3037:** 53, 84. *Mellor* **5:** 822-30: **2:** 310 (1946-1947). *Mellor* **2, Supp. 1:** 60 (1956).
Carbonates	The carbonates of sodium, lithium, calcium and lead in contact with fluorine are decomposed at ordinary temperatures with incandescence. *Mellor* **2:** 13 (1946-1947).
Carbon Disulfide	A mixture of fluorine and carbon disulfide ignites at ordinary temperatures. *Mellor* **2:** 13; **6:** 111 (1946-1947).
Carbon Tetrachloride	The reaction is violent and sometimes explosive. *NASA SP*-**3037:** 82. *Mellor* **2, Supp. I.** 198 (1956).
Cellulose	Fluorine in contact with cotton produces a violent explosion. *Mellor* **2, Supp. 1:** 54 (1956).
Cesium Acetylene Carbide	Cesium acetylene carbide burns in cold fluorine. *Mellor* **5:** 849 (1946-1947).
Cesium Monoxide	See BROMINE plus Cesium Monoxide.
Cesium Perfluoro-propoxide	During preparation of perfluoropropyl hypofluorite, the intermediate cesium compound was being fluorinated with a 50/50 fluorine-nitrogen mix at minus 50¡C. After 10 hours addition of fluorine, the set-up exploded. *Chem. Eng. News* **43** (9): 36 (1965). *MCA Case History* **1045** (1964).
Charcoal	See FLUORINE plus Common Materials and Oxygen.
Chlorides	Chlorides, bromides, iodides and cyanides are generally

	vigorously attacked by fluorine in the cold.
	Mellor **2:** 13 (1946-1947).
Chlorinated Polyethylene	See FLUORINE plus Solid Nonmetals.
Chlorine	See CHLORINE plus Fluorine.
Chlorine Dioxide	The uncontrolled reaction between chlorine dioxide and fluorine is explosive.
	Lawless and Smith, p. 133 (1968).
	Mellor **2, Supp. 1:** 532 (1956).
Chromous Sulfide	Chromous sulfide combines with fluorine with incandescence.
	Mellor **11:** 430 (1946-1947).
Chromyl Chloride	Fluorine reacts with chromyl chloride, producing flame at certain concentrations.
	Mellor **2, Supp. 1:** 64 (1956).
Coke	See FLUORINE plus Common Materials and Oxygen.
Common Materials and Oxygen	Spill tests of 100% liquid fluorine, 30% liquid fluorine-in-oxygen, and 100% liquid oxygen on various common materials demonstrated the following effects of the fluorine content: asphalt and also crushed limestone (calcium carbonate) burned with sputtering and small flames; JP-4 fuel produced loud, rapid explosions and a large fireball; coke burned with a small flame; charcoal burned smoothly with a large, brilliant fireball; and rich soil burned with a bright flame.
	NASA SP-**3037:** 110-119 (1967).
Copper	When fluorine flows too rapidly or under too much pressure in copper tubing, the copper burns in the fluorine atmosphere. See also FLUORINE plus Metals.
	Yunker (1966). *Cady* (1966).
Copper Hydride	See BROMINE plus Copper Hydride.
Cyanides	See FLUORINE plus Chlorides.

Cyanogen	Cyanogen is decomposed by fluorine gas at ordinary temperatures with the production of a white flame. *Mellor* **2:** 13 (1946-1947).
Ferrous Oxide	Fluorine does not act in the cold on ferrous oxide, but with gentle heat a reaction sets in with incandescence. *Mellor* **13:** 715 (1946-1947).
Graphite	Graphite burns in a stream of fluorine. See also FLUORINE plus Carbon. *Mellor* **2, Supp. I:** 198 (1956).
Halogenated Compounds	See FLUORINE plus Hydrogen.
Hexafluoropropylene-Vinylidene Fluoride Copolymer	See FLUORINE plus Solid Nonmetals and Oxygen.
Hydrazine	Spontaneous ignition occurs when these chemicals are mixed. *Mellor* **8, Supp. 2:** 95 (1967).
Hydriodic Acid	The reaction of fluorine with gaseous hydriodic acid is accompanied by flame. *Mellor* **2:** 12 (1946-1947).
Hydrobromic Acid	The reaction of fluorine with gaseous or aqueous hydrobromic acid is accompanied by flame. *Mellor* **2:** 12 (1946-1947).
Hydrocarbons	Violent explosions are encountered when attempts are made to fluorinate hydrocarbons in the liquid phase with elementary fluorine. Many lubricants burn in fluorine. *Mellor* **2: Supp. I:** 198 (1956). *NASA SP*-**3037:** 82-84 (1967). *Mellor* **2, Supp. 1:** 55 (1956).
Hydrochloric Acid	The reaction of fluorine with gaseous or aqueous hydrochloric acid is accompanied by flame.

	Mellor **2:** 12, 204-6 (1946-1947).
Hydrofluoric Acid (Aqueous)	If fluorine is passed into a 50 per cent solution of hydrofluoric acid, there is an energetic reaction with the water and it is accompanied by flame.
	Mellor **2:** 12 (1946-1947).
Hydrogen	Hydrogen and fluorine combine with extreme violence. The reactions of most organic compounds with fluorine occur explosively. Even halogenated organic materials burn or explode in a fluorine atmosphere. The reaction with water is violent even at minus 210¡C.
	Matheson Gas Data, p. 215 (1961). *Stecher*, pp. 301-2 (1953).
	Fluorine and hydrogen react as low as minus 210¡C when impurities are present.
	Mellor **1:** 327 (1946-1947).
Hydrogen Azide	See AZINE FLUORIDE (self-reactive).
Hydrogen Sulfide	Fluorine ignites in contact with hydrogen sulfide.
	Mellor **10:** 133 (1946-1947).
Iodides	See FLUORINE plus Chlorides.
Iodine	Iodine unites with fluorine at ordinary temperatures with a luminous flame.
	Mellor **2:** 12 (1946-1947).
Iridium	See IRIDIUM plus Fluorine.
Iron	See FLUORINE plus Metals. See also IRON plus FLUORINE.
JP-4 Fuel	See FLUORINE plus Common Materials and Oxygen.
Lead Carbonate (Basic)	White lead burns in fluorine. See also FLUORINE plus Carbonates.
	NASA SP-**3037:** 83 (1967).
Lead Oxide and Glycerol	A mixture of litharge and glycerol burns in fluorine.

	NASA SP-**3037:** 84 (1967).
Limestone (crushed)	See FLUORINE plus Common Materials and Oxygen.
Lithium Carbide	See BROMINE plus Lithium Carbide.
Lithium Carbonate	See FLUORINE plus Carbonates.
Lithium Silicide	When lithium silicide is warmed with gaseous fluorine, a reaction takes place with incandescence. With chlorine, bromine, and iodine a higher temperature is required.
	Mellor **6:** 169 (1946-1947).
Lucite	See FLUORINE plus Solid Nonmetals and Oxygen.
Magnesium	See MAGNESIUM plus Fluorine.
Manganese	See MANGANESE plus Fluorine.
Manganous Oxide	See FLUORINE plus Trimanganese Tetroxide.
Manufactured Gas	Unlighted manufactured gas issuing from a gas jet is immediately ignited by fluorine gas.
	Mellor **2:** 13 (1946-1947).
Mercuric Cyanide	Fluorine and mercuric cyanide react vigorously when gently heated, producing flames.
	Mellor **2, Supp. 1:** 63 (1956).
Metals	Metals (powdered) are in general attacked by fluorine at ordinary temperatures. If the temperature is raised nearly all the metals are vigorously attacked with incandescence.
	Mellor **2:** 13 (1946-1947).
	Some average ignition temperatures (¡F) of various metals in fluorine are: aluminum, greater than 1220; copper, 692; iron, 672; molybdenum, 205; monel, 396; nickel, 1162; stainless steel (No. 302), 681; and tungsten, 283.
	NASA SP-**3037:** 79-80 (1967).
Molybdenum	See FLUORINE plus Metals. See also MOLYBDENUM plus FLUORINE.
Monel	See FLUORINE plus Metals.
Neoprene	When pieces of neoprene are dropped into liquid fluorine slight explosions occur and the neoprene burns. Neoprene

	covered fiberglass exploded in liquid fluorine. See also FLUORINE plus Solid Nonmetals.
	NASA SP-**3037:** 84
	Mellor **2, Supp. 1:** 54 (1956).
	Chem. Eng. News **26:** 3336-7 (1948).
Nickel	See FLUORINE plus Metals.
Nickel Monoxide	Nickel monoxide becomes incandescent in fluorine gas.
	Ann. Chim. et Phys. (5) **21:** 199, 386.
	NASA SP-**3037:** 84.
Niobium (Columbium)	See NIOBIUM plus Fluorine.
Nitric Acid	If fluorine is passed into nitric acid, each bubble of gas is attended by the decomposition of the acid and accompanied by flame.
	Ann. Chim. et Phys. (6) **24:** 224.
	Fluorine in contact with nitric acid creates a danger of explosion if acid is not 100% strength.
	Mellor **8, Supp. 2:** 319 (1967).
Nitric Oxide	Fluorine reacts immediately with nitric oxide with a pale yellow flame.
	Ann. Chim. et Phys. (8) **9:** 221.
	Mellor **2, Supp. 1:** 54 (1956).
Nitrogen Dioxide	Fluorine and nitrogen dioxide react vigorously when heated.
	Mellor **2, Supp. 1:** 54 (1956).
Nylon	See FLUORINE plus Solid Nonmetals and Oxygen.
Organic Matter	Fluorine in contact with leather causes it to
(Leather)	smolder and char.
	Mellor **2, Supp. 1:** 54 (1956).
Perchloric Acid	Reaction of fluorine and perchloric acid produces fluorine perchlorate, a highly reactive material.

	Mellor **2, Supp. 1:** 59 (1956).
	See also FLUORINE PERCHLORATE (self-reactive).
	The action of fluorine gas in 60-72% perchloric acid leads to the formation of fluorine perchlorate, a very unstable gas that explodes under the most diverse physical and chemical influences.
	Pascal **16:** 316 (1931-1934). *Kirk and Othmer, Second Ed.* **5:** 74 (1963).
Perfluoropropionyl Fluoride	Fluorination of perfluoropropionyl fluoride to synthesize perfluoropropionyl hypofluorite in the presence of activated cesium fluoride catalyst involves potential explosion hazards. No temperature change was noted during the 10-hour addition of fluorine at minus 40¡C, but the set-up exploded at the finish of the addition.
	MCA Case History **1045** (1965).
	Chem. Eng. News **43:** 36 (March 1, 1965).
Phenol-Formaldehyde Resin	See FLUORINE plus Solid Nonmetals and Oxygen.
Phosphorus	Fluorine reacts with red or yellow phosphorus at ordinary temperatures and the reaction is accompanied by incandescence.
	Mellor **8:** 785 (1946-1947).
	Mellor **2, Supp. 1:** 60 (1956).
	See also PHOSPHORUS plus Chlorine.
Phosphorus Pentachloride	When phosphorus pentachloride is treated with fluorine, the entire mass becomes incandescent.
	Moissan, p. 134 (1900).
Phosphorus Trichloride	Phosphorus trichloride reacts with fluorine with incandescence.
	Moissan, p. 134 (1900).
Phosphorus	A yellow flame appears when fluorine contacts

Trifluoride	phosphorus trifluoride.
	Comp. Rend. **138:** 789.
Polyamide	See FLUORINE plus Solid Nonmetals and Oxygen.
Polychloroprene	See FLUORINE plus Solid Nonmetals and Oxygen.
Polyethylene	See FLUORINE plus Solid Nonmetals and Oxygen.
Polymethylmethacrylate	See FLUORINE plus Solid Nonmetals and Oxygen.
Polytetrafluoroethylene	See FLUORINE plus Solid Nonmetals and Oxygen.
Polyurethane	See FLUORINE plus Solid Nonmetals and Oxygen.
Polyvinylchloride Acetate	See FLUORINE plus Solid Nonmetals and Oxygen.
Potassium	See POTASSIUM plus Fluorine.
Potassium Hydride	See CHLORINE plus Potassium Hydride.
Potassium Nitrate	Fluorine attacks potassium nitrate to give fluorine nitrate.
	Mellor **2, Supp. 1:** 62 (1956).
	See also FLUORINE NITRATE (self-reactive).
Potassium Perchlorate	The action at low pressure of fluorine on potassium perchlorate produces fluorine perchlorate, which is very unstable and explodes easily.
	Pascal **16:** 316 (1931-1934).
Rhenium	See RHENIUM plus Fluorine.
Rubber (LS-53 and LS-63)	See FLUORINE plus Solid Nonmetals and Oxygen.
Rubidium Acetylene Carbide	See BROMINE plus Rubidium Acetylene Carbide.
Selenium	Selenium, silicon, or sulfur ignites in fluorine gas at ordinary temperatures.
	Mellor **2:** 11-13; **6:** 161-4 (1946-1947).
Silicon	See FLUORINE plus Selenium.
Silver Cyanide	Fluorine and silver cyanide react with explosive violence at

	ordinary temperatures.
	Mellor **2, Supp. 1:** 63 (1956).
Sodium	See SODIUM plus Fluorine.
Sodium Acetate	Fluorine and sodium acetate produce an explosive reaction involving formation of diacetyl peroxide.
	Mellor **2, Supp. 1:** 56 (1956).
	See also DIACETYL PEROXIDE (self-reactive).
Sodium Carbonate	See FLUORINE plus Carbonates.
Sodium Hydride	See CHLORINE plus Sodium Hydride.
Sodium Silicate	Sodium silicate (water glass) burns in fluorine.
	NASA SP-**3037:** 82 (1967).
Soil (rich)	See FLUORINE plus Common Materials and Oxygen.
Solid Nonmetals	Numerous nonmetal materials were tested
and Oxygen	statically on gaseous and liquid fluorine-oxygen mixtures with 50 to 100% fluorine. Substances that burned or reacted violently were: Tygon (polyvinyl chloride-acetate), nylon (polyamide), Bakelite (phenol-formaldehyde resin), polyethylene, neoprene (polychloroprene), Buna N (acrylonitrile-butadiene copolymer), LS-53 and LS-63 Rubber (trifluoropropyl methyl polysiloxane), Viton A (vinylidene fluoride-hexafluoropropylene copolymer) and polyurethane foam. Under dynamic conditions, i.e., flow and pressure, other materials such as Lucite (polymethyl methacrylate), Teflon (polytetrafluoroethylene), and CPE products (chlorinated polyethylenes) also ignited in fluorine-oxygen mixtures.
	NASA SP-**3037:** 87-110 (1967).
Stainless Steel (302)	See FLUORINE plus Metals.
Strontium Phosphide	Mixtures of these materials ignite at room temperatures.
	Mellor **8:** 841 (1946-1947).
Sulfur	See FLUORINE plus Selenium.
Sulfur Dioxide	Each bubble of sulfur dioxide gas led into a container of

	fluorine produces an explosion.
	Mellor **2:** 1 (1946-1947)
Tantalum	Fluorine attacks powdered tantalum with incandescence.
	Mellor **9:** 891 (1946-1947).
	Fluorine reacts vigorously with tantalum. The metal should not be used to handle it.
	Mellor **2, Supp. 1:** 62 (1956).
Teflon□	See FLUORINE plus Solid Nonmetals and Oxygen.
Tellurium	Fluorine attacks tellurium with incandescence.
	Mellor **11:** 26, 40 (1946-1947).
Thallium	Fluorine acts so vigorously on thallium that the metal becomes incandescent.
	Mellor **5:** 421, 434 (1946-1947).
Thallous Chloride	Fluorine and thallous chloride react violently, melting the product.
	Mellor **2, Supp. 1:** 63 (1956).
Titanium	When titanium is fractured in a liquid fluorine atmosphere, it ignites. With catalysis, titanium has ignited in gaseous fluorine at minus 113¡ F.
	NASA SP-**3037:** 70 (1967).
Trifluoropropyl Methyl	See FLUORINE plus Solid Nonmetals and
Polysiloxane	Oxygen.
Trimanganese	Fluorine and trimanganese tetroxide or manganous
Tetroxide	oxide react vigorously below 100¡ C, even when diluted with nitrogen.
	Mellor **2, Supp. 1:** 64 (1956).
Tungsten	The reaction between fluorine and tungsten is accompanied by incandescence. See also FLUORINE plus Metals.
	Mellor **11:** 730 (1946-1947).
Tungsten Carbide	Tungsten carbide becomes incandescent in cold fluorine.

	Mellor **5:** 890 (1946-1947).
Tygon	See FLUORINE plus Solid Nonmetals and Oxygen.
Uranium	Electrolytic uranium, as fine powder, is vigorously attacked by fluorine, and burns. Uranium ignites spontaneously in cold fluorine.
	Mellor **2:** 13; **12:** 31, 32 (1946-1947).
Uranium Carbide	See BROMINE plus Uranium Dicarbide.
Viton A	See FLUORINE plus Solid Nonmetals and Oxygen.
Water	Water *vapor* will react combustively with fluorine; an explosive reaction occurs between liquid fluorine and ice, after an intermediate induction period.
	NASA SP-**3037:** 52 (1967).
	If liquid air which has stood for some time is treated with fluorine, a precipitate is formed which is very likely to explode. Explosive material is thought to be fluorine hydrate.
	Mellor **2:** 11 (1946-1947).
	See also FLUORINE plus Hydrogen.
Zinc	Zinc burns in moist fluorine.
	Mellor **4:** 476 (1946-1947).
Zirconium Dicarbide	See BROMINE plus Zirconium Dicarbide.

FLUORINE AZIDE N_3F

(self-reactive)	Azine fluoride was detected in the products obtained from the reaction of fluorine with nitrogen-diluted hydrogen azide. The liquid is extremely shock- and light-sensitive and often explodes on vaporization.
	Lawless and Smith, p. 104 (1968).
	Fluorine azide is extremely unstable and easily decomposes explosively.
	Mellor **2, Supp. 1:** 59 (1956).

Mellor **8, Supp. 2:** 24 (1967).

FLUORINE FLUOROSULFATE FSO_2OF

(self-reactive)	Fluorine fluorosulfate, which has a vapor pressure of 10 atmospheres at room temperature, was distilled cold into a steel cylinder rated at 135 atmospheres. When the cylinder reached room temperature, it exploded. The violence indicated a chemical explosion.
	Chem. Eng. News **44:** 40 (Feb. 21, 1966).
	MCA Case History **1189** (1966).

FLUORINE NITRATE $FONO_2$

(self-reactive)	Fluorine nitrate explodes on slight concussion.
	Merck Index, p. 464 (1968).

FLUORINE PERCHLORATE $FOClO_3$

(self-reactive)	Pure fluorine perchlorate exploded in three attempts to determine its freezing point. The gas readily explodes on contact with a small flame or spark.
	ACS **146:** 209. *J. Am. Chem. Soc.* **69:** 667-8 (1947).
	Mellor **2, Supp. 1:** 59, 184 (1956).
	See also POTASSIUM PERCHLORATE plus Fluorine.
Organic Matter	Fluorine perchlorate undergoes explosive decomposition on contact with grease, dirt, or rubber tubing.
	Mellor **2, Supp. 1:** 184 (1956).
Potassium Iodide	A sample of fluorine perchlorate exploded on contact with a potassium iodide solution.
	ACS **146:** 209-10. *J. Am. Chem. Soc.* **69:** 667-8 (1947).
	Fluorine perchlorate in contact with potassium iodide can cause an explosion.

Mellor **2, Supp. 1:** 184 (1956).

FLUORINE PEROXIDE F_2O_2

(self-reactive)

Fluorine peroxide is a very unstable vapor above minus 100¡ C, decomposing to fluorine and oxygen gases.

Mellor **2, Supp. 1:** 194 (1956).

FLUOROACETYLENE HC≡CF

(self-reactive)

Fluoroacetylene is a colorless gas that freezes at minus 196¡ C to a white solid, which melts to a liquid whose boiling point is a little below minus 80¡ C. The liquid sometimes explodes with great force. The silver salt detonates when warmed, and the mercury salt decomposes violently without detonation when warmed.

Rutledge, p. 135 (1968).

FLUOROCHLORO-LUBRICANTS

Aluminum

See ALUMINUM plus Fluorochloro-lubricants.

FLUORODIMETHYLARSINE $(CH_3)_2AsF$

Air

Dimethylfluoroarsine is spontaneously flammable in air.

Ripley (1966).

1-FLUORO-2,2-DINITROETHANE $CH_2FCH(NO_3)_2$

Air

Abnormal operating conditions during the nitration process in preparation of dinitrofluoroethane caused the operator to relieve the vacuum by introducing air. The resulting reaction with air caused an explosion.

MCA Case History **784** (1962).

FORMALDEHYDE HCHO

Nitrogen Dioxide	The slow reaction between nitrogen dioxide and formaldehyde becomes explosive in the region of 180¡ C. F. H. Pollard and P. Woodward, *Trans. Faraday Soc.* **45:** 767-770 (1949).
Perchloric Acid and Aniline	See PERCHLORIC ACID plus Aniline and Formaldehyde.
Performic Acid	See PERFORMIC ACID plus Formaldehyde.

FORMAMIDINE THIOLACETIC ACID HYDROCHLORIDE

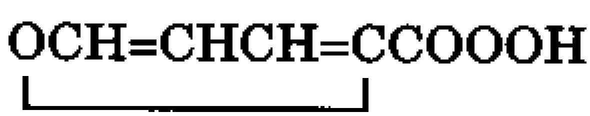
$NH_2C(NH)SCH_2COOH \cdot HCl$

Chlorine	See CHLORINE plus S-Ethyl Isothiourea Sulfate.

FORMIC ACID HCOOH

Furfuryl Alcohol	See FURFURYL ALCOHOL plus Formic Acid.
Hydrogen Peroxide	See HYDROGEN PEROXIDE plus Formic Acid and Organic Matter.
Thallium Trinitrate Trihydrate	See THALLIUM TRINITRATE TRIHYDRATE plus Formic Acid.

FURAN-2-PEROXYCARBOXYLIC ACID



(self-reactive)	This acid explodes when heated to 30 to 40¡ C, or at room temperature upon addition of organic or inorganic materials such as carbon black, calcium chloride, barium chloride, strontium chloride or magnesium chloride. *Chem. Reviews* **45:** 15, 16 (1949).

FURFURYL ALCOHOL $OCH{=}CHCH{=}CCH_2OH$

Cyanoacetic Acid	An explosion occurred in a laboratory when cyanoacetic acid was reacted with furfuryl alcohol in an attempt to form the ester, furfuryl cyanoacetate. The explosion occurred a few minutes after the agitator was turned on and the heat applied.
	MCA Case History **858** (1963).
Formic Acid	During an attempt to prepare furfuryl formate from furfuryl alcohol and concentrated formic acid, an explosion occurred.
	Chem. Eng. News **18:** 72 (1940).
Mineral Acids	Furfuryl alcohol will polymerize rapidly, and sometimes with explosive violence, in the presence of strong mineral acids.
	Hexagon Alpha Chi Sigma (October 1949).
Nitric Acid	See NITRIC ACID plus Organic Matter.
	See NITRIC ACID plus Furfuryl Alcohol.
	See also NITRIC ACID plus Diborane.
Nitric Acid, Nitrogen Tetroxide, and Sulfuric Acid	See UNSYMMETRICAL DIMETHYLHYDRAZINE plus Nitric Acid, Nitrogen Tetroxide, and Sulfuric Acid.

GADOLINIUM Gd

Air	See RARE EARTH METALS plus Air.
Halogens	See RARE EARTH METALS plus Halogens.

GALLIC ACID $(OH)_3C_6H_2COOH$

Potassium Chlorate	See POTASSIUM CHLORATE plus Gallic Acid.

GALLIUM HYDRIDE Ga_2H_6

Air	Gallium hydride is spontaneously flammable in air.
	Hurd, p. 99 (1952).

GALLIUM PERCHLORATE $Ga(ClO_3)_3$

Urea	The double salt formed decomposes violently on heating.
	Mellor **2, Supp. 1:** 611 (1956).

GALLIUM TRIETHYL $(C_2H_5)_3Ga$

(See TRIETHYL GALLIUM)

GALLIUM TRIMETHYL $(CH_3)_3Ga$

(See TRIMETHYL GALLIUM)

GERMANE (GERMANIUM HYDRIDE) GeH_4

Air	The germanium hydrides are spontaneously flammable in air.
	Fawcett (1965). *Brauer* (1965).

GERMANIUM

Bromine	When heated in bromine, germanium burns with a yellowish flame.
	Mellor **7:** 260 (1946-1947).
Chlorine	When germanium is heated in chlorine, it burns with a bluish-white flame. Powdered germanium ignites spontaneously in chlorine at ordinary temperatures.
	Mellor **7:** 260 (1946-1947).
Nitric Acid	The action of concentrated nitric acid on powdered

	germanium is very violent.
	Mellor **7:** 260 (1946-1947).
Oxygen	Germanium burns with incandescence when heated in oxygen.
	Mellor **7:** 260 (1946-1947).
Potassium Chlorate	See GERMANIUM plus Potassium Nitrate.
Potassium Nitrate	Mixture of germanium with potassium nitrate or potassium chlorate explodes when heated.
	Mellor **7:** 261 (1946-1947).

GERMANIUM HYDRIDE GeH_4

Air	See GERMANE plus Air.

GERMANIUM HYDRIDES GeH_4; Ge_2H_6; Ge_3H_8

Air	The germanium hydrides decompose in air, often bursting into flames.
	Brauer (1965).

GERMANIUM SULFIDE GeS_2

Potassium Nitrate	When germanium sulfide is mixed with potassium nitrate and heated, it explodes.
	Mellor **7:** 274 (1946-1947).

GERMANIUM TETRACHLORIDE $GeCl_4$

Water	Germanium tetrachloride is decomposed by water and much heat is developed.
	Mellor **7:** 270 (1946-1947).

GERMANIUM TETRAIODIDE GeI_4

Air	The vapor of germanium tetraiodide is flammable in air.
	Mellor **7:** 272, 273 (1946-1947).

GLASS

Chlorine Trifluoride	See CHLORINE TRIFLUORIDE plus Charcoal.

GLYCERIDES $(RCOOCH_2)CHOCOR$

Nitric Acid and Sulfuric Acid	See NITRIC ACID plus Sulfuric Acid and Glycerides.

GLYCEROL $HOCH_2CHOHCH_2OH$

Acetic Anhydride	See ACETIC ANHYDRIDE plus Glycerol.
Aniline and Nitrobenzene	See ANILINE plus Nitrobenzene and Glycerine.
Calcium Hypochlorite	See CALCIUM HYPOCHLORITE plus Glycerol and CALCIUM HYPOCHLORITE plus Ethyl Alcohol.
Chlorine	See CHLORINE plus Polypropylene.
Chromic Anhydride	See CHROMIC ANHYDRIDE plus Naphthalene.
Chromium Oxide	See CHROMIUM OXIDE plus Glycerol.
Fluorine and Lead Oxide	See FLUORINE plus Lead Oxide and Glycerol.
Perchloric Acid and Lead Oxide	See LEAD OXIDE plus Perchloric Acid and Glycerine.
Potassium Permanganate	See POTASSIUM PERMANGANATE plus Glycerol.
Potassium Peroxide	See SODIUM PEROXIDE plus Aniline.
Silver Perchlorate	See SILVER PERCHLORATE plus Acetic Acid.

Sodium Peroxide	See SODIUM PEROXIDE plus Aniline.

GLYCOL ETHERS

Perchloric Acid	See PERCHLORIC ACID plus Glycol Ethers.

GLYCOLONITRILE $HOCH_2CN$

(self-reactive)	A bottle containing freshly purified glycolonitrile sat for a week before a portion of it was removed. Six days later, the remainder polymerized and exploded the bottle. *Chem. Eng. News* **42** (48): 50 (Nov. 28, 1966).

GLYCOL PERCHLORATES

(self-reactive)	Glycol perchlorate and epichlorohydrin perchlorate are more explosive than nitroglycerine. Ethylene glycol perchlorate is so sensitive that a few drops of water cause a violent explosion. *ACS* **146:** 214. *Berichte* **42:** 2031-4 (1909).

GLYCOLS

Perchloric Acid	See PERCHLORIC ACID plus Glycol Ethers.

GLYOXAL OCHCHO

(self-reactive)	See GLYOXAL plus Water.
Air	Mixtures with air may explode. *Merck Index,* p. 502 (1968). See also GLYOXAL plus Water.
Chlorosulfonic Acid	Mixing glyoxal and chlorosulfonic acid in a closed container caused the temperature and pressure to increase. *Flynn and Rossow* (1970). See Note under complete reference.

Ethyleneimine	Mixing glyoxal and ethyleneimine in a closed container caused the temperature and pressure to increase.
	Flynn and Rossow (1970). See Note under complete reference.
Nitric Acid	See NITRIC ACID plus Glyoxal.
Oleum	Mixing glyoxal and oleum in a closed container caused the temperature and pressure to increase.
	Flynn and Rossow (1970). See Note under complete reference.
Sodium Hydroxide	See SODIUM HYDROXIDE plus Glyoxal.
Water	Glyoxal polymerizes quickly on standing, on contact with water (violent reaction), or when dissolved in solvents containing water.
	Merck Index, p. 502 (1968).

GOLD Au

Ammonia	The reaction between ammonia and gold, silver, or mercury produces fulminate-like compounds of variable and uncertain composition that explode when dried. Severe accidents have occurred.
	Chem. Abst. **60:** 12, 14327 (1964).
	Mellor **3:** 579-84 (1946-1947).
	Allison (1966). J. K. Luchs, *Phot. Sci. Eng.* **10:** 334-7 (1966).
Ammonium Hydroxide	In an effort to precipitate finely divided gold
and Aqua Regia	from aqua regia, ammonium hydroxide was substituted for ammonium oxalate. When the gold precipitate was heated in a muffle furance with other metals to produce an alloy, an explosion occurred.
	U. Wash. Occ. Health Newsletter **16** (1967).
Hydrogen Peroxide	Finely divided gold and a strong hydrogen peroxide solution may explode.
	Mellor **1:** 936 (1946-1947).

GOLD CYANIDE $AuCN$; $Au(CN)_3 \cdot 3H_2O$

Magnesium	See MAGNESIUM plus Gold Cyanide.

GOLD SALTS

Nitromethane	See COPPER SALTS plus Nitromethane.

GRAPHITE C

Chlorine Trifluoride	See CHLORINE TRIFLUORIDE plus Charcoal.
Fluorine	See FLUORINE plus Charcoal.
Potassium	See POTASSIUM plus Charcoal.
Potassium Superoxide	See POTASSIUM plus Graphite and Air. Also see POTASSIUM plus Graphite and Potassium Superoxide.

GUANIDINE NITRATE $H_2NC(NH)NH_2HNO_3$

(self-reactive)	See AMMONIUM THIOCYANATE plus Lead Nitrate.

GUANIDINE PERCHLORATE $(NH_2)_3CClO_4$

(self-reactive)	Guanidine perchlorate is unusually sensitive to initiation and has extraordinary explosive power. *ACS* **146:** 213 *Davis* (1943).

HAFNIUM BOROHYDRIDE

(See HAFNIUM TETRAHYDROBORATE)

HAFNIUM TETRAHYDROBORATE $Hf(BH_4)_4$

Air	Hafnium borohydride burns violently when exposed to air. *Gaylord*, p. 58 (1966).

HALOGENATED HYDROCARBONS

(See specific halogenated hydrocarbon; see also under other reactant)

HALOGEN FLUORIDES

Organic Matter	See BROMINE MONOFLUORIDE plus Water. See individual fluoride plus Organic Matter.

HALOGENS

Cerium	See RARE EARTH METALS plus Halogens.
Dysprosium	See RARE EARTH METALS plus Halogens.
Erbium	See RARE EARTH METALS plus Halogens.
Europium	See RARE EARTH METALS plus Halogens.
Gadolinium	See RARE EARTH METALS plus Halogens.
Hafnium	See RARE EARTH METALS plus Halogens.
Holmium	See RARE EARTH METALS plus Halogens.
Lutetium	See RARE EARTH METALS plus Halogens.
Neodymium	See RARE EARTH METALS plus Halogens.
Praseodymium	See RARE EARTH METALS plus Halogens.
Rare Earth Metals	See RARE EARTH METALS plus Halogens.
Samarium	See RARE EARTH METALS plus Halogens.
Terbium	See RARE EARTH METALS plus Halogens.
Thulium	See RARE EARTH METALS plus Halogens.
Tri-iso-Butyl Aluminum	See TRI-iso-BUTYL ALUMINUM plus Acids.

Ytterbium	See RARE EARTH METALS plus Halogens.
Yttrium	See RARE EARTH METALS plus Halogens.

HEPTANE C_7H_{16}

Phosphorus and Chlorine	See PHOSPHORUS plus Chlorine and Heptane.

HEXABORANE (10) B_6H_{10}

Air	Boron hexahydride is spontaneously flammable in air. *Douda* (1966).

HEXABORANE (12) B_6H_{12}

Air	This hydride is spontaneously flammable in air. *Mellor* **5:** 36 (1946-1947). *Douda* (1966).

HEXACHLOROBENZENE C_6Cl_6

Dimethyl Formamide	See DIMETHYL FORMAMIDE plus Hexachlorobenzene.

HEXACHLOROMELAMINE $N{=}C(NCl_2)N{=}C(NCl_2)N{=}C(NCl_2)$

Acetone	See HEXACHLOROMELAMINE plus Organic Contaminants.
Ammonia	See HEXACHLOROMELAMINE plus Organic Contaminants.
Aniline	See HEXACHLOROMELAMINE plus Organic Contaminants.
Diphenylamine	See HEXACHLOROMELAMINE plus Organic Contaminants.

Organic Contaminants	Organic contaminants added to hexachloromelamine cause a very rapid reaction to take place with or without visible flame. Contaminants tested were acetone, aniline, diphenylamine, ammonia and others. The hexachloromelamine would explode if the amount were large and confined. Trichloromelamine behaves similarly; however, it consumes itself less rapidly, but with more flame and fume production. After the contaminant is added, there is a delay of several seconds before anything happens.
	Ventrone (1968).
Turpentine	See HEXACHLOROMELAMINE plus Organic Contaminants.

1,5-HEXADIEN-3-YNE $H_2C{=}CHC{\equiv}CCH{=}CH_2$

Air	Divinylacetylene reacts with oxygen to form an explosive peroxide polymer. Divinylacetylene must be handled in an oxygen-free atmosphere. After experiments are completed the equipment should be rinsed immediately with solvents containing a polymerization inhibitor to prevent formation of unstable films. Handy and Bensen, *J. Org. Chem.* **27:** 39 (1962).

2, 4-HEXADIYN-1, 6-BISCHLOROSULFITE $(ClSOOCH_2C{\equiv}C\text{-})_2$

(self-reactive)	See THIONYL CHLORIDE plus 2, 4-Hexadiyn-1, 6-Diol.
	2, 4-hexadiyn-1, 6-bischlorosulfite is shock-sensitive and decomposes violently upon distillation.
	P. E. Drieder and H. V. Isaacson, *Chem. Eng. News* **50** (12): 51 (1972).

2, 4-HEXADIYN-1, 6-DIOL $(HOCH_2C{\equiv}C\text{-})_2$

Phosgene	See PHOSGENE plus 2, 4-Hexadiyn-1, 6-Diol.
Thionyl Chloride	See THIONYL CHLORIDE plus 2, 4-Hexadiyn-1, 6-Diol.

HEXAFLUOROPROPYLENE-VINYLIDINE COPOLYMER

Fluorine	See FLUORINE plus Solid Nonmetals and Oxygen.

HEXAMETHYLBENZENE $C_6(CH_3)_6$

Nitromethane	The electro-oxidation of various methyl benzenes was being studied. During the reactions, violent explosions occurred at the auxiliary electrode. *Chem. Eng. News* **49** (23): 6 (1971).

HEXAMETHYLENE DIISOCYANATE $OCN(CH_2)_6NCO$

Alcohols	See ALCOHOLS plus Isocyanates.

HEXAMETHYLENETETRAMINE $(CH_2)_6N_4$

Sodium Peroxide	See SODIUM PEROXIDE plus Hexamethylenetetramine.

HEXAMMINE CHROMIUM NITRATE

(See CHROMIC-HEXAMMINE NITRATE)

HEXAMMINE COBALT IODATE

(See COBALTIC-HEXAMMINE IODATE)

HEXAMMINE COBALT PERCHLORATE

(See COBALTIC-HEXAMMINE PERCHLORATE)

HEXAMMINOCADMIUM CHLORATE

(See CADMIUM-HEXAMMINE CHLORATE)

HEXAMMINOCADMIUM PERCHLORATE $Cd(NH_3)_6(ClO_4)_2$

(See CADMIUM-HEXAMMINE PERCHLORATE)

HEXAMMINO CALCIUM

(See CALCIUM HEXAMMONIATE)

HEXAMMINOCOBALT CHLORATE $Co(NH_3)_6(ClO_3)_2$

(See COBALT-HEXAMMINE CHLORATE)

HEXAMMINOCOBALTIC CHLORITE $Co(NH_3)_6ClO_2.3H_2O$

(See COBALTIC-HEXAMMINE CHLORITE)

HEXAMMINOCOBALT PERCHLORATE $Co(NH_3)_6(ClO_4)_2$

(See COBALT-HEXAMMINE PERCHLORATE)

HEXAMMINONICKEL CHLORATE $Ni(NH_3)_6(ClO_3)_2$

(See NICKEL-HEXAMMINE CHLORATE)

HEXAMMINONICKEL PERCHLORATE $Ni(NH_3)_6(ClO_4)_2$

(See NICKEL-HEXAMMINE PERCHLORATE)

HOLMIUM Ho

Air	See RARE EARTH METALS plus Air.
Halogens	See RARE EARTH METALS plus Halogens.

HYDRAZINE H_2NNH_2

Air	Hydrazine may ignite spontaneously while absorbed on

	porous materials such as earth, asbestos, cloth, or wood unless the heat of the gradual hydrazine-air reaction has a chance to dissipate. Spontaneous ignition can occur with hydrogen peroxide and nitric acid. Contact with many metallic oxide surfaces may lead to flaming decomposition.
	Haz. Chem. Data (1966).
	Mellor **8, Supp. 2:** 95 (1967).
Alkali Metals and	Explosive metal hydrazides form when hydrazine
Ammonia	and alkali metals are mixed in liquid ammonia.
	Mellor **8, Supp. 2:** 73 (1967).
Chlorine	See CHLORINE plus Hydrazine.
Chromates	See CHROMATES plus Hydrazine.
Cupric Oxide	See CUPRIC OXIDE plus Hydrazine.
Cupric Salts	See CUPRIC SALTS plus Hydrazine.
Fluorine	See FLUORINE plus Hydrazine.
Hydrogen Peroxide	See HYDRAZINE plus Air.
	Mellor **8, Supp. 2:** 95 (1967).
Iron Oxide	While boiling a sample of a polyester fiber in hydrazine in a glass beaker, the technician used a somewhat rusty pair of metal tweezers to handle the sample. When the tweezers were put in the solution, the solution ignited. The ignition temperature of hydrazine varies from 75¡ F in the presence of iron oxide to 518¡ F in a glass container.
	MCA Case History **1893** (1973).
Metallic Oxides	See HYDRAZINE plus Air.
Nickel	See NICKEL plus Hydrazine.
Nickel Perchlorate	See NICKEL PERCHLORATE plus Hydrazine.
Nitric Acid	See HYDRAZINE plus Air.
	Spontaneous ignition occurs when these chemicals are mixed.
	Mellor **8, Supp. 2:** 95 (1967).

Nitrous Oxide	See NITROUS OXIDE plus Lithium Hydride.
Oxygen	See OXYGEN plus Hydrazine.
Oxygen (liquid)	See OXYGEN (LIQUID) plus Hydrazine.
Potassium Dichromate	See POTASSIUM DICHROMATE plus Hydrazine.
Sodium Dichromate	See POTASSIUM DICHROMATE plus Hydrazine.
Tetryl	During the measurement of shock sensitivity of a mixture containing hydrazine, a drop of the hydrazine mixture fell inadvertently on the tetryl donor explosive. The tetryl immediately burst into flame. *ASESB Operational Incident Report* **105**.
Zinc Diamide	See ZINC DIAMIDE plus Hydrazine.
Zinc Diethyl	See ZINC DIAMIDE plus Hydrazine.

HYDRAZINE AZIDE $H_2NNH_3N_3$

(self-reactive)	This is an explosive salt. *Mellor* **8, Supp. 2:** 86 (1967).
Air	When hydrazine azide is rapidly heated in air, as by a white-hot wire, the salt decomposes violently. Similar explosions occur when a detonator is used. The moist salt is also explosive. *Mellor* **8:** 344 (1946-1947).

HYDRAZINE CHLORITE $H_2NNH_3ClO_2$

(self-reactive)	This is an explosive salt, highly flammable when dry. *Mellor* **8, Supp. 2:** 85 (1967). *Mellor* **2, Supp. 1:** 573 (1956).

HYDRAZINE HYDRATE $H_2NNH_2 \cdot H_2O$

2,4-Dinitrochlorobenzene	This reaction is exothermic; it shattered the reaction flask.

	Wischmeyer (1967).
Mercuric Oxide	See MERCURIC OXIDE plus Hydrazine Hydrate.
Sodium	See SODIUM plus Hydrazine Hydrate.
Stannous Chloride	See STANNOUS CHLORIDE plus Hydrazine Hydrate.

HYDRAZINE MONONITRATE $H_2NNH_2HNO_3$

Copper	See ZINC plus Hydrazine Mononitrate.
Metal Carbides	See ZINC plus Hydrazine Mononitrate.
Metal Nitrides	See ZINC plus Hydrazine Mononitrate.
Metal Oxides	See ZINC plus Hydrazine Mononitrate.
Metal Sulfides	See ZINC plus Hydrazine Mononitrate.
Zinc	See ZINC plus Hydrazine Mononitrate.

HYDRAZINE NITRATE $H_2NNH_3NO_3$

(self-reactive)	This explosive salt is less stable than ammonium nitrate. *Mellor* **8, Supp. 2:** 86 (1967).

HYDRAZINE PERCHLORATE $H_2NNH_3ClO_4$

(self-reactive)	Dry hydrazine perchlorate can be detonated by shock or friction. *ACS*-**146:** 209. *Comp. Rend.* **228:** 1497-8 (1949). *Mellor* **8, Supp. 2:** 85 (1967).

HYDRAZINE SELENATE $H_2NNH_2SeO_3OH$

(self-reactive)	This salt is explosive. *Mellor* **8, Supp. 2:** 85 (1967).

HYDRAZOIC ACID N_3H

Cadmium	See CADMIUM plus Hydrazoic Acid.
Copper	See COPPER plus Hydrazoic Acid.
Nickel	See NICKEL plus Hydrazoic Acid.
Nitric Acid	The reaction of hydrazoic acid and nitric acid is energetic. *Mellor* **8, Supp. 2:** 4 (1967).

HYDRIDES

(See specific hydrides as primary entries or see under other reactants)

HYDRIODIC ACID HI

(See also HYDROGEN IODIDE)

Fluorine	See FLUORINE plus Hydriodic Acid.
Perchloric Acid	See PERCHLORIC ACID plus Hydriodic Acid.

HYDROBROMIC ACID HBr

Fluorine	See FLUORINE plus Hydrobromic Acid.

HYDROCARBONS

Chlorine	See CHLORINE plus Hydrocarbons.
Fluorine	See FLUORINE plus Hydrocarbons.
Magnesium Perchlorate	See MAGNESIUM PERCHLORATE plus Hydrocarbons.

HYDROCHLORIC ACID HCl

(See also HYDROGEN CHLORIDE)

Acetic Anhydride	See ACETIC ANHYDRIDE plus Hydrochloric Acid.
2-Aminoethanol	See 2-AMINOETHANOL plus Hydrochloric Acid.
Ammonium Hydroxide	Mixing hydrochloric acid and 28% ammonia in a closed container caused the temperature and pressure to increase. *Flynn and Rossow* (1970). See Note under complete reference.
Calcium Phosphide	See CALCIUM PHOSPHIDE plus Hydrochloric Acid.
Chlorosulfonic Acid	See CHLOROSULFONIC ACID plus Hydrochloric Acid.
Ethylene Diamine	See ETHYLENE DIAMINE plus Hydrochloric Acid.
Ethyleneimine	See ETHYLENEIMINE plus Hydrochloric Acid.
Oleum	See OLEUM plus Hydrochloric Acid.
Perchloric Acid	The hydronium compound decomposes spontaneously with violence. *Mellor* **2, Supp. 1:** 613 (1956).
Propiolactone (beta-)	See PROPIOLACTONE (beta-) plus Hydrochloric Acid.
Propylene Oxide	See PROPYLENE OXIDE plus Hydrochloric Acid.
Silver Perchlorate and Carbon Tetrachloride	See SILVER PERCHLORATE plus Carbon Tetrachloride and Hydrochloric Acid.
Sodium Hydroxide	See SODIUM HYDROXIDE plus Hydrochloric Acid.
Sulfuric Acid	Mixing 36% hydrochloric acid and 96% sulfuric acid in a closed container caused the temperature and pressure to increase. *Flynn and Rossow* (1970). See Note under complete reference.
Uranium Phosphide	See URANIUM PHOSPHIDE plus Hydrochloric Acid.
Vinyl Acetate	See VINYL ACETATE plus Hydrochloric Acid.

HYDROFLUORIC ACID HF

(See also HYDROGEN FLUORIDE)

Acetic Anhydride	See ACETIC ANHYDRIDE plus Hydrofluoric Acid.
2-Aminoethanol	See 2-AMINOETHANOL plus Hydrofluoric Acid.
Ammonium Hydroxide	Mixing 48.7% hydrofluoric acid and 28% ammonia in a closed container caused the temperature and pressure to increase.
	Flynn and Rossow (1970). See Note under complete reference.
Bismuthic Acid	See BISMUTHIC ACID plus Hydrofluoric Acid.
Calcium Oxide	See CALCIUM OXIDE plus Hydrofluoric Acid.
Chlorosulfonic Acid	See CHLOROSULFONIC ACID plus Hydrofluoric Acid.
Ethylene Diamine	See ETHYLENE DIAMINE plus Hydrofluoric Acid.
Ethyleneimine	See ETHYLENEIMINE plus Hydrofluoric Acid.
Fluorine	See FLUORINE plus Hydrofluoric Acid.
Nitric Acid and Lactic Acid	See NITRIC ACID plus Lactic Acid and Hydrofluoric Acid.
Oleum	See OLEUM plus Hydrofluoric Acid.
Propiolactone (beta-)	See PROPIOLACTONE (beta-) plus Hydrofluoric Acid.
Propylene Oxide	See PROPYLENE OXIDE plus Hydrofluoric Acid.
Sodium	See SODIUM plus Hydrofluoric Acid.
Sodium Hydroxide	See SODIUM HYDROXIDE plus Hydrofluoric Acid.
Sulfuric Acid	Mixing 48.7% hydrofluoric acid and 96% sulfuric acid in a closed container caused the temperature and pressure to increase.
	Flynn and Rossow (1970). See Note under complete reference.
Vinyl Acetate	See VINYL ACETATE plus Hydrofluoric Acid.

HYDROGEN H_2

Air and Platinum	Finely divided platinum and some other metals will cause a

	mixture of hydrogen and oxygen to explode at ordinary temperatures. If a jet of hydrogen in air impinges on platinum black, the metal becomes hot enough to ignite the gas.
	Mellor **1:** 325; **16:** 146 (1946-1947).
Bromine	See BROMINE plus Hydrogen.
Chlorine	See CHLORINE plus Hydrogen.
Chlorine Trifluoride	See CHLORINE TRIFLUORIDE plus Ammonia.
Dioxane and Nickel	Dioxane reacts explosively with hydrogen and
(Raney)	Raney nickel above 210¡C.
	Organic Synthesis, **Coll. Vol. III:** 182 (1955).
Fluorine	See FLUORINE plus Hydrogen.
Lithium	See LITHIUM plus Hydrogen.
Magnesium and	See MAGNESIUM plus Hydrogen and Calcium
Calcium Carbonate	Carbonate.
Nitroanisole	Catalytic hydrogenation of nitroanisole in the presence of nickel catalyst has resulted in an explosion.
	J. Am. Chem. Soc. **53:** 2417 (1931).
Nitrogen Trifluoride	Explosive reactions occur upon ignition of mixtures of nitrogen trifluoride with good reducing agents such as ammonia, carbon monoxide, hydrogen, hydrogen sulfide or methane.
	Lawless and Smith, p. 34 (1968).
Oxygen Difluoride	Mixtures of hydrogen, carbon monoxide, or methane and oxygen difluoride are exploded when a spark is discharged.
	Mellor **2, Supp. 1:** 192 (1956).
Oxygen and Platinum	See HYDROGEN plus Air and Platinum.
Palladium and	When a stream of hydrogen entrained isopropyl
Isopropyl Alcohol	alcohol vapors and palladium particles, the mixture caught fire on exposure to air.
	Confidential information furnished to NFPA.

1-Pentol	An explosion and subsequent investigation revealed that heating 1'-pentol and 1"-pentol under hydrogen pressure is extremely dangerous. It appears to cause this acetylenic compound to break down suddenly to elemental carbon, hydrogen, and carbon monoxide with the release of sufficient energy to develop pressures in excess of 1,000 atmospheres. The presence of small quantities of sulfuric acid or potassium hydroxide reduces the temperature of instability of 1-pentol. Also heating 1-pentol isomers above 100¡C during vacuum distillation should be avoided to prevent polymerization.
	F. Lorenz, *AIChE Loss Prevention, 1967,* p. 1.

HYDROGEN AZIDE HN_3

Fluorine	See AZINE FLUORIDE (self-reactive).

HYDROGEN BROMIDE HBr

Ammonia	The reaction is vigorous even at minus 80¡C with intensely dried reactants.
	Mellor **2, Supp. 1:** 737 (1956).
Ozone	See OZONE plus Hydrogen Bromide.

HYDROGEN CHLORIDE HCl

(See also HYDROCHLORIC ACID)

Calcium Carbide	See CALCIUM CARBIDE plus Hydrogen Chloride.
Cesium Acetylene Carbide	See CESIUM ACETYLENE CARBIDE plus Hydrogen Chloride.
Cesium Carbide	See CESIUM CARBIDE plus Hydrochloric Acid.
Dowicil 100	See DOWICIL 100 plus Hydrogen Chloride.
Lithium Silicide	See LITHIUM SILICIDE plus Hydrogen Chloride.
Magnesium Boride	See MAGNESIUM BORIDE plus Hydrochloric Acid.

Mercuric Sulfate	See MERCURIC SULFATE plus Hydrogen Chloride.
Rubidium Acetylene Carbide	See RUBIDIUM ACETYLENE CARBIDE plus Hydrochloric Acid.
Rubidium Carbide	See RUBIDIUM CARBIDE plus Hydrochloric Acid.
Sodium	See SODIUM plus Hydrochloric Acid.
	See SODIUM plus Hydrogen Chloride.

HYDROGEN CYANIDE HCN

(self-reactive)	Hydrogen cyanide containing water up to 10% was polymerized in glass ampoules at 50-60¡C or catalyzed at room temperature under the effect of a minute amount of alkali. In view of the possibility of running into dangerous conditions with a water content of 2-5%, it is important to keep it below this range.
	J. Chem. Soc. Japan Ind. Chem. Sec. **71** (8): 1119-1123 (1968).
Acetaldehyde	See ACETALDEHYDE plus Ammonia (Anhydrous).

HYDROGEN DIPHOSPHIDE P_2H

Air	Hydrogen diphosphide in air ignites when suddenly heated to 100¡C., or when struck with a hammer.
	Mellor **8:** 831 (1946-1947).

HYDROGEN FLUORIDE HF

(See also HYDROFLUORIC ACID)

Arsenic Trioxide	Hydrogen fluoride and arsenic trioxide react with incandescence.
	Mellor **9:** 101 (1946-1947).
Phosphorus Pentoxide	See PHOSPHORUS PENTOXIDE plus Hydrogen Fluoride.

HYDROGEN IODIDE HI

(See also HYDRIODIC ACID)

Magnesium	See MAGNESIUM plus Hydrogen Iodide.
Nitric Acid	When hydrogen iodide is passed through fuming nitric acid, each bubble produces a red flame with the separation of iodine. *Berichte* **3:** 3660.
Ozone	See OZONE plus Hydrogen Iodide.
Potassium	See POTASSIUM plus Hydrogen Iodide.
Potassium Chlorate	See POTASSIUM CHLORATE plus Hydrogen Iodide.

HYDROGEN PEROXIDE H_2O_2

Acetic Acid	Even dilute hydrogen peroxide added to dilute acetic acid and heated will initiate an exothermic reaction with production of peracetic acid which will explode at 110¡C. *Weed* (1966).
Acetic Anhydride	Addition of hydrogen peroxide to acetic anhydride yields peroxyacetic acid; but an excess of acetic anhydride reacts with peroxyacetic acid yielding diacetyl peroxide, which is very unstable and explodes readily. *Chem. Reviews* **45:** 5 (1949). See also HYDROGEN PEROXIDE plus Acetic Acid. See also PERACETIC ACID plus Acetic Anhydride.
Acetone	See HYDROGEN PEROXIDE plus Organic Matter.
Alcohols and Sulfuric Acid	See ALCOHOLS plus Hydrogen Peroxide and Sulfuric Acid.
Antimony Trisulfide	See ANTIMONY TRISULFIDE plus Hydrogen Peroxide.
Arsenic Trisulfide	See ANTIMONY TRISULFIDE plus Hydrogen Peroxide.
Brass	See IRON plus Hydrogen Peroxide.

Bronze	See IRON plus Hydrogen Peroxide.
t-Butyl Alcohol	The preparation of di tertiary butyl peroxide by the addition of tertiary butyl alcohol to a mixture of hydrogen peroxide and sulfuric acid (2 to 1 weight ratio of 78% sulfuric acid to 50% hydrogen peroxide) has resulted in severe explosions particularly during the early stages of large batches.
	T.A. Schenach, *Chem. Eng. News.* **51** (6): 39 (Feb. 5, 1973).
Cellulose	Hydrogen peroxide plus cellulose (in cotton) ignites spontaneously.
	Mellor **1:** 938 (1946-1947).
Charcoal	Charcoal mixed with a trace of manganese dioxide ignites immediately in contact with hydrogen peroxide.
	Mellor **1:** 938 (1946-1947).
Chlorine and Potassium Hydroxide	See CHLORINE plus Hydrogen Peroxide and Potassium Hydroxide.
Chlorosulfonic Acid	See CHLOROSULFURIC ACID plus Hydrogen Peroxide.
Chromium	See IRON plus Hydrogen Peroxide.
Copper	See IRON plus Hydrogen Peroxide.
Cupric Sulfide	See ANTIMONY TRISULFIDE plus Hydrogen Peroxide.
Dimethylbenzylcarbinol and Sulfuric Acid	See ALCOHOLS plus Hydrogen Peroxide and Sulfuric Acid.
Ethyl Alcohol	See ETHYL ALCOHOL plus Hydrogen Peroxide.
Ethyl Alcohol and Sulfuric Acid	See ALCOHOLS plus Hydrogen Peroxide and Sulfuric Acid.
Ferrous Sulfide	See ANTIMONY TRISULFIDE plus Hydrogen Peroxide.
Formic Acid and Organic Matter	A chemist working with a 50-50 mixture of formic acid and 90 per cent hydrogen peroxide, introduced a small amount of organic material into the solution. When

	the reaction had subsided, the container was removed to a workbench. Later, when the flask was picked up, the material exploded violently.
	Chem. Eng. News **28:** 418 (1950).
Gold	See GOLD plus Hydrogen Peroxide.
Hydrazine	See HYDRAZINE plus Air.
	See HYDRAZINE plus Hydrogen Peroxide.
Hydrogen Selenide	See HYDROGEN SELENIDE plus Hydrogen Peroxide.
Iron	See IRON plus Hydrogen Peroxide.
Ketones and	See KETONES plus Nitric Acid and Hydrogen
Nitric Acid	Peroxide.
Lead	See IRON plus Hydrogen Peroxide.
Lead Dioxide	See LEAD DIOXIDE plus Hydrogen Peroxide.
Lead Monoxide	See LEAD DIOXIDE plus Hydrogen Peroxide.
Lead Sulfide	See ANTIMONY TRISULFIDE plus Hydrogen Peroxide.
Magnesium	See MAGNESIUM plus Hydrogen Peroxide.
Manganese	See IRON plus Hydrogen Peroxide.
Manganese Dioxide	See MANGANESE DIOXIDE plus Hydrogen Peroxide.
Mercuric Oxide	See LEAD DIOXIDE plus Hydrogen Peroxide.
Mercurous Oxide	See MERCUROUS OXIDE plus Hydrogen Peroxide.
Molybdenum Disulfide	See ANTIMONY TRISULFIDE plus Hydrogen Peroxide.
Nitric Acid	This mixture is unstable when more than 50% of acid is present.
	Mellor **8, Supp. 2:** 315 (1967).
Organic Matter	Under certain circumstances, hydrogen peroxide is capable of developing an explosive power in excess of its weight equivalent of TNT when mixed with organic compounds; the acetone-hydrogen peroxide system is a good example.
	Chem. Safety Data Sheet **SD-53** (1955). **SD-53 Supp. A** (1961). **SD-53 Supp. B** (1961).

	BCISC **36:** 29 (July-Sept. 1969). *BCISC* **40** (158): 17 (1969). *Chem. in Brit.* **5** (1): 36 (1969).
	Chem. in Brit. **5** (6): 287 (1969).
1-Phenyl-2-methyl-propyl Alcohol and Sulfuric Acid	See ALCOHOLS plus Hydrogen Peroxide and Sulfuric Acid.
Platinum	See PLATINUM plus Hydrogen Peroxide.
Potassium	See LEAD DIOXIDE plus Hydrogen Peroxide.
Potassium Permanganate	See POTASSIUM PERMANGANATE plus Hydrogen Peroxide.
Silver	See IRON plus Hydrogen Peroxide.
	See SILVER plus Hydrogen Peroxide.
Sodium	See LEAD DIOXIDE plus Hydrogen Peroxide.
Sodium Iodate	See SODIUM IODATE plus Hydrogen Peroxide.
Thiodiglycol	See THIODIGLYCOL plus Hydrogen Peroxide.
Unsymmetrical Dimethyl Hydrazine	See UNSYMMETRICAL DIMETHYL HYDRAZINE plus Hydrogen Peroxide.

HYDROGEN PHOSPHIDE

(See DIPHOSPHINE)

HYDROGEN SELENIDE SeH_2

Hydrogen Peroxide	Hydrogen selenide and hydrogen peroxide undergo a very swift decomposition.
	Mellor **1:** 941 (1946-1947).
Nitric Acid	Fuming nitric acid reacts with incandescence with hydrogen selenide.
	Berichte **3:** 658.

HYDROGEN SULFIDE H_2S

Acetaldehyde	See ACETALDEHYDE plus Ammonia (Anhydrous).
Barium Oxide, Mercurous Oxide and Air	See HYDROGEN SULFIDE plus Soda Lime.
Barium Oxide, Nickel Oxide and Air	See HYDROGEN SULFIDE plus Soda Lime.
Bromine Pentafluoride	See BROMINE PENTAFLUORIDE plus Acetic Acid.
Chlorine Monoxide	Hydrogen sulfide ignites in contact with chlorine monoxide.
	Mellor **10:** 134 (1946-1947).
Chlorine Trifluoride	See CHLORINE TRIFLUORIDE plus Ammonia.
Chromic Anhydride	See CHROMIC ANHYDRIDE plus Hydrogen Sulfide. Also see CHROMIC ANHYDRIDE plus Naphthalene.
Copper	See COPPER plus Hydrogen Sulfide.
Fluorine	See FLUORINE plus Hydrogen Sulfide.
Hydrated Iron Oxide	A pyrophoric iron sulfide was made from hydrated iron oxide and hydrogen sulfide under gasoline.
	Ellern, p. 33 (1968).
Lead Dioxide	See LEAD DIOXIDE plus Hydrogen Sulfide.
Nitric Acid	Fuming nitric acid reacts with incandescence with hydrogen sulfide.
	Berichte **3:** 658.
	Chem. Safety Data Sheet **SD-5,** p. 6.
Nitrogen Iodide	See BROMINE plus Nitrogen Triiodide.
Nitrogen Trichloride	See NITROGEN TRICHLORIDE plus Ammonia.
Nitrogen Trifluoride	See HYDROGEN plus Nitrogen Trifluoride.
Oxygen Difluoride	See OXYGEN DIFLUORIDE plus Hydrogen Sulfide.

Phenyl Diazonium Chloride	See PHENYL DIAZONIUM CHLORIDE plus Hydrogen Sulfide.
Soda Lime (Sodium Hydroxide and Calcium Oxide) and Air	The reaction between hydrogen sulfide and soda lime is attended with incandescence in the presence of air; in oxygen, there is a violent explosion. Mixtures of barium oxide with mercurous or nickel oxide also react vigorously with hydrogen sulfide in air and vivid incandescence or explosions may result. *Mellor* **10:** 140 (1946-1947).
Sodium	See SODIUM plus Hydrogen Sulfide.
Sodium Peroxide	When hydrogen sulfide is passed over sodium peroxide, a very vigorous reaction occurs, even in the absence of air, and the reaction may be accompanied by flame. *Mellor* **10:** 132 (1946-1947).

HYDROGEN TELLURIDE H_2Te

Nitric Acid	See NITRIC ACID plus Hydrogen Telluride.

HYDROGEN TRISULFIDE HSSSH

Amyl Alcohol	The decomposition of amyl alcohol by hydrogen trisulfide is explosively violent. *Mellor* **10:** 158 (1946-1947).
Iron Oxide (Magnetite)	See HYDROGEN TRISULFIDE plus Lead Oxide.
Lead Oxide	Lead oxide, stannic oxide, and magnetite (Fe_3O_4) brought about a violent decomposition of hydrogen trisulfide. *Mellor* **10:** 159 (1946-1947).
Potassium Permanganate	Potassium permanganate decomposes hydrogen trisulfide so rapidly that sufficient heat is liberated to ignite the trisulfide.

	Mellor **10:** 159 (1946-1947).
Stannic Oxide	See HYDROGEN TRISULFIDE plus Lead Oxide.

HYDROQUINONE $C_6H_4(OH)_2$

Sodium Hydroxide	See SODIUM HYDROXIDE plus Hydroquinone.

HYDROXIDES

(See also specific hydroxides as primary entries or see under other reactants)

Acrolein	See SODIUM HYDROXIDE plus Acrolein.

4-HYDROXY-3, 5-DINITROBENZENEAR SONIC ACID

$4,3,5,1\text{-}OHC_6H_2(NO_2)_2AsO_3H_2$

(self-reactive)	This compound and its metallic salts may be as explosive as its close relative picric acid. When a wet cake of the acid was heated an explosion occurred that was accompanied by liberation of arsenic or arsine.
	M. A. Phillips, *Chem. & Ind.* **1947:** 61.

a-HYDROXYISOBUTYRONITRILE $(CH_3)_2COHCN$

Sulfuric Acid	During addition of sulfuric acid to a vat of acetone cyanhydrin, pressure produced by rapid reaction ruptured the vessel explosively.
	Occupancy Fire Record **FR57-5:** 5 (1957).

HYDROXYLAMINE NH_2OH

Barium Dioxide	See BARIUM DIOXIDE plus Hydroxylamine.
Barium Oxide	See BARIUM OXIDE plus Hydroxylamine.
Chlorine	See CHLORINE plus Hydroxylamine.
Copper Sulfate	See COPPER SULFATE plus Hydroxylamine

Lead Dioxide	See LEAD DIOXIDE plus Hydroxylamine.
Phosphorus Pentachloride	See PHOSPHORUS TRICHLORIDE plus Hydroxylamine.
Phosphorus Trichloride	See PHOSPHORUS TRICHLORIDE plus Hydroxylamine.
Potassium Dichromate	See POTASSIUM DICHROMATE plus Hydroxylamine.
Potassium Permanganate	See POTASSIUM PERMANGANATE plus Hydroxylamine.
Sodium	See SODIUM plus Hydroxylamine.
Zinc	See ZINC plus Hydroxylamine.

HYDROXYLAMINE HYPOPHOSPHITE $NH_2OHPH_2O_2$

(self-reactive) Hydroxylamine hypophosphite detonates above 100¡ C.

Mellor **8:** 880 (1946-1947).

HYDROXYLAMINES

(See also under other reactants)

(self-reactive) Several scale-ups of previously successful hydroxylamine reactions have resulted in explosions, e.g.: 1) During preparation of an oxime from an aldehyde, an ether solution of the reaction mixture, containing hydroxylamine hydrochloride decomposed violently under vacuum distillation at 80¡ C. 2) The hydrochloride can be made to decompose exothermically at 140¡ C. and solid hydroxylamine sulfate will explode when heated to 170¡ C. 3) A mixture containing the hydrochloride, pyridine, and sodium acetate in a stainless steel autoclave at 90¡ C. suddenly heated and pressurized to 5000 psi to rupture the relief disk.

Chem. Process (Chicago) **26:** 30 (1963).

4-HYDROXY-3-METHOXYBENZALDEHYDE

$CH_3O(HO)C_6H_3CHO$

(See VANILLIN.)

Bromine	See BROMINE plus Methyl Alcohol.
Perchloric Acid	See PERCHLORIC ACID plus Ethyl Alcohol.
Potassium Tert.-Butoxide	See ACETONE plus Potassium Tert.-Butoxide.
Tetrachlorobenzene and Sodium Hydroxide	See SODIUM HYDROXIDE plus Tetrachlorobenzene and Methyl Alcohol.

n-HYDROXYMETHYLACRYLAMIDE $HOCH_2NHCOCH{=}CH_2$

Contaminant	Among four fiber drums of this chemical, two of which had never been opened, excessive heat, smoke, crackling, and small flames were noted. Very small amounts of contaminant are believed to have catalyzed this polymerization reaction, but storage in excessively heated areas can also start the reaction. *Coventry* (1965). *Spence* (1966).

3-HYDROXYPROPIONITRILE $HOCH_2CH_2CN$

Chlorosulfonic Acid	Mixing ethylene cyanohydrin and chlorosulfonic acid in a closed container caused the temperature and pressure to increase. *Flynn and Rossow* (1970). See Note under complete reference.
Oleum	See OLEUM plus Ethylene Cyanohydrin.
Sodium Hydroxide	See SODIUM HYDROXIDE plus Ethylene Cyanohydrin.
Sulfuric Acid	Mixing ethylene cyanohydrin and 96% sulfuric acid in a closed container caused the temperature and pressure to increase. *Flynn and Rossow* (1970). See Note under complete reference.

HYPOCHLORITES

(See also specific hypochlorites as primary entries or under other reactants)

Urea	Hypochlorites react with urea to form nitrogen trichloride which explodes spontaneously in air.
	J. Am. Chem. Soc. **63:** 3530-32.

HYPOCHLOROUS ACID HOCl

Alcohols	See ALCOHOLS plus Hypochlorous Acid.
Ammonia	Gaseous ammonia explodes in contact with hypochlorous acid; toxic chlorine is liberated.
	Mellor **8:** 217 (1946-1947).
Arsenic	See ARSENIC plus Hypochlorous Acid.

HYPOPHOSPHITES

(See specific hypophosphites as primary entries or see under other reactants.)

Perchloric Acid	Some inorganic materials, such as hypophosphites, tend to form explosive mixtures with perchloric acid when hot. When a precipitate of scandium hypophosphite was heated in a perchloric acid solution, the perchloric acid concentrated from evaporation and the mixture of perchloric acid with the inorganic reducing compound exploded violently.
	Analyst **84:** 215 (April 1959). *NSC Newsletter, Chem. Sec.* (November 1966).

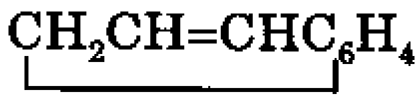
HYPOPHOSPHORIC ACID $H_4P_2O_6$

Mercuric Nitrate	See MERCURIC NITRATE plus Hypophosphoric Acid.

HYPOPHOSPHOROUS ACID H_3PO_2

Mercuric Oxide — See MERCURIC OXIDE plus Hypophosphorous Acid.

INDANE



Nitric Acid and Sulfuric Acid — In the preparation of 4 and 5 nitroindanes according to the procedure of Lindner and Brukin (*Chem. Ber.* **60,** 435 (1925)) the crude nitro mix was distilled in vacuo. After allowing the pot to cool, air was admitted to the residue. After a short period the pot erupted. A second preparation exploded at the beginning of the distillation.

G.W. Grebble, *Chem. Eng. News* **51** (6): 39 (Feb. 5, 1973).

INDIUM In

Sulfur — When indium is heated with sulfur, the elements unite with incandescence.

Mellor **5:** 393 (1946-1947).

INDIUM MONOXIDE InO

Air — Indium monoxide is spontaneously flammable in air.

Ellern (1961).

INDIUM TRIETHYL $(C_2H_5)_3In$

(See TRIETHYL INDIUM)

INDIUM TRIPROPYL $(C_3H_7)_3In$

(See TRIPROPYL INDIUM)

IODATES

(See also specific iodates as primary entries or under other reactants)

Aluminum	See ALUMINUM plus Bromates.
Arsenic	See ARSENIC plus Bromates.
Carbon	See CARBON plus Bromates.
Copper	See COPPER plus Bromates.
Metal Sulfides	See METAL SULFIDES plus Bromates.
Organic Matter	See BROMATES plus Organic Matter.
Phosphonium Iodide	See BROMATES plus Phosphonium Iodide.
Phosphorus	See PHOSPHORUS plus Bromates.
Sulfur	See SULFUR plus Bromates.

IODIC ACID HIO_3

Boron	See BORON plus Iodic Acid.
Phosphonium Iodide	See PHOSPHONIUM IODIDE plus Bromic Acid.

IODIDES

(See specific iodides as primary entries or under other reactants)

IODINE I_2

Acetaldehyde	See BROMINE plus Acetaldehyde.
Acetylene	Acetylene can react explosively with iodine.
	Von Schwartz, p. 142 (1918).
Aluminum	See ALUMINUM plus Iodine.
Ammonia	Mixture explodes spontaneously.
	Von Schwartz, p. 324 (1918).

Ammonium Hydroxide	The reaction of excess iodine with strong aqueous ammonium hydroxide forms explosive iodide.
	Mellor **8, Supp. 1:** 330 (1964).
	Nitrogen iodides, which detonate on drying, are formed from concentrated solutions.
	Mellor **2, Supp. 1:** 851 (1956).
Antimony	See ANTIMONY plus Bromine.
Bromine Pentafluoride	See ARSENIC plus Bromine Pentafluoride.
	An immediate reaction with evolution of heat occurs between iodine and bromine pentafluoride.
	Mellor **2, Supp. 1:** 173 (1956).
Cesium Acetylene Carbide	Cesium Acetylene Carbide burns in the vapors of iodine.
	Mellor **5:** 844 (1946-1947).
Cesium Carbide	Cesium carbide, rubidium carbide or lithium carbide (after warming) burn in iodine vapor.
	Mellor **5:** 848 (1946-1947).
Cesium Monoxide	See BROMINE plus Cesium Monoxide.
Chlorine	See CHLORINE plus Iodine.
Chlorine Trifluoride	See CHLORINE TRIFLUORIDE plus Mercuric Iodide.
Cuprous Acetylide	See BROMINE plus Cuprous Acetylide.
Ethyl Alcohol, Methyl Alcohol, and Mercuric Oxide	The Petrov method of preparing 1-iodo-2-ethoxy-3-butene calls for addition of 15 grams of mercuric oxide to 0.11 molar ethyl alcohol in 25 ml of methyl alcohol, followed by 25 grams of powdered iodine at -10 to -15¡ C, filtration, and dilution. A change in the procedure used 1 molar ethyl alcohol. While the alcohol was being distilled off under vacuum, a violent explosion occurred.
	Chem. Eng. News **44** (42): 7 (October 17, 1966).

	Chem. Abst. **44:** 1003-d (1950).
Fluorine	See FLUORINE plus Iodine.
Lithium	A highly luminous reaction occurs at room temperature, between iodine and lithium, potassium, and sodium.
	Mellor **2, Supp. 1:** 848 (1956).
Lithium Carbide	See BROMINE plus Lithium Carbide.
	See IODINE plus Cesium Carbide.
Lithium Silicide	See FLUORINE plus Lithium Silicide.
Magnesium	See MAGNESIUM plus Iodine.
Oxygen Difluoride	See BROMINE plus Oxygen Difluoride.
Phosphorus	Ordinary (white or yellow) phosphorus unites with iodine at ordinary temperatures. Even at minus 24¡C., heat is developed. The product is spontaneously flammable in air. With red phosphorus, the reaction does not occur at ordinary temperatures; but when warmed, it reacts without incandescence.
	C.L. Gazzaniga, *Bibl. Univ. Genéve* **54:** 186 (1833).
	See also PHOSPHORUS plus Oxygen.
Potassium	Potassium burns on contact with liquid iodine.
	Mellor **2:** 469 (1946-1947).
	Iodine and potassium vapors at 0.001 mm pressure react with luminescence.
	Mellor **2, Supp. 3:** 1563 (1963).
Rubidium Acetylene	See BROMINE plus Rubidium Acetylene
Carbide	Carbide.
Rubidium Carbide	See IODINE plus Cesium Carbide.
Silver Azide	Silver azide in a cold ethereal solution of iodine gives a yellow explosive, iodoazide.
	Mellor **8:** 336-7 (1946-1947).
Sodium Hydride	Sodium hydride reacts with iodine with incandescence at 100¡C.

	Mellor **2:** 483 (1946-1947).
Zirconium Dicarbide	See BROMINE plus Zirconium Dicarbide.

IODINE AZIDE N_3I

(self-reactive)	Iodine azide is spontaneously explosive.
	Mellor **8:** 336 (1946-1947).
	Mellor **8, Supp. 2:** 50 (1967).

IODINE HEPTAFLUORIDE IF_7

Ammonium Bromide	Iodine heptafluoride reacts violently with ammonium bromide, ammonium chloride or ammonium iodide.
	Mellor **2, Supp. 1:** 179 (1956).
Ammonium Chloride	See IODINE HEPTAFLUORIDE plus Ammonium Bromide.
Ammonium Iodide	See IODINE HEPTAFLUORIDE plus Ammonium Bromide.
Carbon Monoxide	Carbon monoxide burns in gaseous iodine heptafluoride.
	Mellor **2, Supp. 1:** 179 (1956).
Organic Matter	See BROMINE MONOFLUORIDE plus Water.
Sulfuric Acid	In reaction between iodine heptafluoride and sulfuric acid, the acid becomes effervescent.
	Mellor **2, Supp. 1:** 185 (1956).
Water	See BROMINE MONOFLUORIDE plus Water.

IODINE MONOBROMIDE IBr

Phosphorus	See PHOSPHORUS plus Iodine Monobromide.
Potassium	See POTASSIUM plus Iodine Monobromide.
Sodium	See SODIUM plus Ferrous Chloride.

	See SODIUM plus Iodine Monobromide.

IODINE MONOCHLORIDE ICl

Aluminum Foil	See ALUMINUM plus Iodine Monochloride.
Cadmium Sulfide	The reaction between iodine monochloride and cadmium sulfide, lead sulfide, silver sulfide, or zinc sulfide is vigorous.
	Mellor **2, Supp. 1:** 502 (1956).
Lead Sulfide	See IODINE MONOCHLORIDE plus Cadmium Sulfide.
Organic Matter	Iodine monochloride produces a vigorous reaction with cork, rubber and other organic substances.
	Mellor **2, Supp. 1:** 500 (1956).
Phosphorus	See PHOSPHORUS plus Iodine Monobromide.
Phosphorus Trichloride	The reaction of iodine monochloride and phosphorus trichloride is intensely exothermal.
	Mellor **2, Supp. 1:** 502 (1956).
Potassium	See POTASSIUM plus Iodine Monochloride.
Rubber	See IODINE MONOCHLORIDE plus Organic Matter.
Silver Sulfide	See IODINE MONOCHLORIDE plus Cadmium Sulfide.
Sodium	See POTASSIUM plus Iodine Monochloride.
	See SODIUM plus Iodine Monochloride.
Zinc Sulfide	See IODINE MONOCHLORIDE plus Cadmium Sulfide.

IODINE PENTAFLUORIDE IF_5

Arsenic	See ARSENIC plus Iodine Pentafluoride.
Bismuth	See ARSENIC plus Iodine Pentafluoride.
Dimethyl Sulfoxide	See DIMETHYL SULFOXIDE plus Iodine Pentafluoride.
Organic Matter	See ARSENIC plus Iodine Pentafluoride.

	See also BROMINE MONOFLUORIDE plus Water.
	See also IODINE PENTAFLUORIDE plus Water.
Phosphorus	See ARSENIC plus Iodine Pentafluoride.
Potassium	See POTASSIUM plus Iodine Pentafluoride.
Silicon	See ARSENIC plus Iodine Pentafluoride.
Sodium	See POTASSIUM plus Iodine Pentafluoride.
Sulfur	See ARSENIC plus Iodine Pentafluoride.
Tetrafluoroethylene and Limonene	Compressed gas cylinders made of tetrafluoroethylene were being purged with nitrogen. Failure of a ball check valve in a related system caused the purge gas to be contaminated with iodine pentafluoride. The iodine pentafluoride reacted with the polymerization inhibitor, limonene, in the TFE, generating enough heat to cause deflagration of the cylinder material.
	MCA Case History **1520** (1968).
Tetraiodoethylene	Explosions occur with too rapid admixture of iodine pentafluoride and tetraiodoethylene.
	Mellor **2, Supp. 1:** 176 (1956).
Tungsten	See ARSENIC plus Iodine Pentafluoride.
Water	Iodine pentafluoride reacts violently with water.
	Matheson Gas Data, p. 254 (1961).
	The reaction between iodine pentafluoride and water is violent. Water-containing materials and many organics also react violently.
	Mellor **2, Supp. 1:** 176 (1956).
	See also BROMINE MONOFLUORIDE plus water.

IODINE PENTOXIDE I_2O_5

Carbon	See CARBON plus Iodine Pentoxide.
Organic Matter	See CARBON plus Iodine Pentoxide.

Sulfur	See CARBON plus Iodine Pentoxide.

IODODIACETYLENE HC≡CC≡CI

(self-reactive)	Iododiacetylene detonates if scratched in light. *Rutledge*, p. 137 (1968).

IODODIMETHYLARSINE $(CH_3)AsI$

Air	Dimethyliodarsine is spontaneously flammable in air. *Ripley* (1966).

2-IODO-3, 5-DINITROBIPHENYL $IC_6H_2(NO_2)_2C_6H_5$

Ethyl Sodio-Acetoacetate	The condensation of 2-iodo-3, 5-dinitrobiphenyl with ethyl sodio-aceto-acetate should be carried out with only 5-6 grams of the 2-iodo-3, 5-dinitrobiphenyl since larger amounts lead to explosions. S.H. Zahur and I.K. Kocker. *J. Indian Chem. Soc.* **32:** 491 (1955).

IODOFORM CHI_3

Lithium	See LITHIUM plus Bromoform.

3-IODO-1-PHENYL-1-PROPYNE $C_6H_5C{\equiv}C{\bullet}CH_2I$

(self-reactive)	While being distilled at about 180¡ C 3-iodo-1-phenyl-1-propyne detonated. *Chem. Eng. News* **50** (23): 86, 87 (June 5, 1972).

IRIDIUM Ir

Chlorine Trifluoride	Chlorine trifluoride reacts with iridium with incandescence.

	Mellor **15:** 745 (1946-1947).
	Mellor **2, Supp. 1:** 156 (1956).
Fluorine	Powdered iridium and fluorine react vigorously at 260¡ C, forming the hexafluoride.
	Mellor **2, Supp. 1:** 65 (1956).
Oxygen Difluoride	An incandescent reaction occurs when any of the following metals are warmed gently in gaseous oxygen difluoride: iridium, osmium, palladium, platinum, rhodium, ruthenium.
	Mellor **2, Supp. 1:** 192 (1956).

IRIDIUM-AMMINE NITRATES

(self-reactive)	Iridium-ammine nitrates may be impact-sensitive.
	$Ir(NH_3)_5OH(NO_3)_3$ and Ir $(NH_3)_5Cl(NO_3)_3$ detonate at red heat.
	Mellor **15:** 787 (1946-1947).

IRIDIUM-AMMINE PERCHLORATES

(self-reactive)	Iridium-ammine perchlorates may be impact-sensitive.
	Mellor **15:** 787 (1946-1947).

IRON Fe

(For iron compounds see also FERRIC and FERROUS compounds)

Chlorine	Hot iron (wire) burns in chlorine gas.
	Mellor **2:** 95, 469 (1946-1947).
	Mellor **2, Supp. 1:** 380 (1956).
Chlorine Trifluoride	Chlorine trifluoride reacts with iron with incandescence.
	Mellor **13:** 315 (1946-1947).
	Mellor **2, Supp. 1:** 156 (1956).
Fluorine	Powdered iron reacts with fluorine below redness with

	incandescence.
	Mellor **13:** 314 (1946-1947).
Hydrogen Peroxide	Violent decomposition of hydrogen peroxide (52% by weight or greater) may be caused by contact with many substances, such as iron, copper, chromium, brass, bronze, lead, silver, manganese, etc., and their salts.
	Chem. Safety Data Sheet **SD-53** (1955); **SD-53 Supp. A** (1961); **SD-53 Supp. B** (1961).
	Iron and hydrogen peroxide ignite immediately if a trace of manganese dioxide is present.
	Mellor **1:** 938 (1946-1947).
Nitrogen Dioxide	Reduced iron decomposes nitrogen dioxide at ordinary temperatures with incandescence.
	Mellor **13:** 342 (1946-1947).
Phosphorus	See COPPER plus Phosphorus.
Sodium Carbide	See MERCURY plus Sodium Carbide.
Sulfuric Acid	While steel piping, which had held sulfuric acid in cold climates during the winter, was being refitted, two explosions occurred; these were possibly due to trapped hydrogen from the acid-metal reaction.
	Chem. Eng. News **29:** 1770 (1951). *Chem. Eng. News* **30:** 707 (1952).

IRON ALLOYS

(See LITHIUM plus Cobalt Alloys)

IRON CARBIDE FeC_2

Bromine	See CHLORINE plus Iron Carbide.
Chlorine	See CHLORINE plus Iron Carbide.

IRON OXIDE Fe_2O_3

Hydrazine	See HYDRAZINE plus Iron Oxide.

IRON OXIDE (MAGNETITE) Fe_3O_4

Hydrogen Trisulfide	See HYDROGEN TRISULFIDE plus Iron Oxide.

IRON PENTACARBONYL $Fe(CO)_5$

Air	Iron pentacarbonyl is spontaneously flammable in air. R. Kamo, *IIT Progs. Rept. 1,* p. 23 (1962).

ISOAMYL NITRITE $(CH_3)_2CHCH_2CH_2ONO$

(self-reactive)	Vapors will explode when heated. *Von Schwartz and Salter,* p. 322 (1940).

ISOBUTANETHIOL $(CH_3)_2CHCH_2SH$

Calcium Hypochlorite	See CALCIUM HYPOCHLORITE plus 1-Propanethiol.

ISOBUTYL METHYL KETONE $CH_3COCH_2CH(CH_3)_2$

Potassium Tert.-Butoxide	See ACETONE plus Potassium Tert.-Butoxide.

ISOBUTYROPHENONE $(CH_3)_2CHCOC_6H_5$

Bromine	See BROMINE plus Isobutyrophenone.

ISOCYANATES	See ALCOHOLS plus Isocyanates.

ISOCYANOETHANE C_2H_5NC

(self-reactive)	Ethyl isonitrile is reported to have exploded when heated on a hot plate.

	Chem. Eng. News **46** (42): 7 (1968).

ISOCYANOMETHANE CH_3NC

(self-reactive)	The dehydration of n-methyl formamide by benzenesulfonyl chloride in tributylamine solution produces methyl isonitrile. In a subsequent distillation, the isonitrile was allowed to go to dryness and the flask exploded.
	Chem. Eng. News **46** (42): 7 (1968).

ISOPRENE $CH_2=C(CH_3)CH=CH_2$

Chlorosulfonic Acid	Mixing isoprene and chlorosulfonic acid in a closed container caused the temperature and pressure to increase.
	Flynn and Rossow (1970). See Note under complete reference.
Nitric Acid	Mixing isoprene and 70% nitric acid in a closed container caused the temperature and pressure to increase.
	Flynn and Rossow (1970). See Note under complete reference.
Oleum	Mixing isoprene and oleum in a closed container caused the temperature and pressure to increase.
	Flynn and Rossow (1970). See Note under complete reference.
Sulfuric Acid	Mixing isoprene and 96% sulfuric acid in a closed container caused the temperature and pressure to increase.
	Flynn and Rossow (1970). See Note under complete reference.

ISOPROPYL ALCOHOL $(CH_3)_2CHOH$

Hydrogen and Palladium	See HYDROGEN plus Palladium and Isopropyl Alcohol.

Nitroform	See NITROFORM plus Isopropyl Alcohol.
Oleum	See OLEUM plus Isopropyl Alcohol.
Phosgene	The reaction between isopropyl alcohol and phosgene forms isopropyl chloroformate and hydrogen chloride. In the presence of iron salts thermal decomposition can occur, which in some cases can become explosive.
	Konstantinov, I.I, Pereslegina, L.S., Zhuravlev, E.Z., and Gusev, Yu. M.
	Tr. po Khim. i Khim. Teknol. **10** (2): 171-4 (1967).
Potassium Tert.-Butoxide	See ACETONE plus Potassium Tert.-Butoxide.

ISOPROPYL CHLOROFORMATE $(CH_3)_2CHOCOCl$

(self-reactive)	Isopropylchloroformate stored in a refrigerator exploded.
	Wischmeyer (1973).
	See also ISOPROPYL ALCOHOL plus Phosgene.

ISOPROPYL ETHER

(See DIISOPROPYL ETHER)

ISOPROPYL HYPOCHLORITE $(CH_3)_2CHOCl$

(self-reactive)	Isopropyl hypochlorite decomposes explosively when exposed to light and rapidly even in its absence.
	Mellor **2, Supp. 1:** 550 (1956).
	See also ALCOHOLS plus Hypochlorous Acid.

JP-4 FUEL

Fluorine	See FLUORINE plus Common Materials and Oxygen.

KETONES

(See also specific ketones)

Acetaldehyde	See ACETALDEHYDE plus Acid Anhydrides.
Nitric Acid	See NITRIC ACID plus Ketones (Cyclic).
Nitric Acid and Hydrogen Peroxide	These reactants produce solids or oils that are highly explosive. The reaction itself proceeds explosively with excess of nitric acid or inadequate cooling.
	Trans. Roy. Soc. Can. **Sect. III 44:** 1934-5 (1954).
Perchloric Acid	See PERCHLORIC ACID plus Glycol Ethers.

LACTIC ACID $CH_3CHOHCOOH$

Nitric Acid and Hydrofluoric Acid	See NITRIC ACID plus Lactic Acid and Hydrofluoric Acid.

LANTHANUM La

Air	See RARE EARTH METALS plus Air.
Halogens	See RARE EARTH METALS plus Halogens.
Phosphorus	See CERIUM plus Phosphorus.

LANTHANUM OXIDE La_2O_3

Chlorine Trifluoride	See CHLORINE TRIFLUORIDE Plus Arsenic Trioxide.

LANTHANUM PHOSPHIDE LaP

Water	See CEROUS PHOSPHIDE plus Water.

LEAD Pb

Ammonium Nitrate	See AMMONIUM NITRATE plus Metals (powdered)
Chlorine Trifluoride	See ALUMINUM plus Chlorine Trifluoride.

Hydrogen Peroxide	See IRON plus Hydrogen Peroxide.
Sodium Azide	See SODIUM AZIDE plus Copper.
Sodium Carbide	See MERCURY plus Sodium Carbide.
Zirconium	An alloy of 10% to 70% zirconium plus lead will ignite when struck with a hammer. *U.S. Pat.* 2,611,316 (1952).

LEAD ACETATE $(CH_3COO)_2Pb$

Potassium Bromate	See POTASSIUM BROMATE plus Lead Acetate.

LEAD AZIDE $Pb(N_3)_2$

(self-reactive)	Lead azide decomposes at 250¡ C. It is explosively unstable. *Mellor* **8, Supp. 2:** 43 (1967). See also SODIUM AZIDE plus Copper.
Brass	See COPPER plus Lead Azide.
Calcium Stearate	In the production of lead azide, addition of calcium stearate was tried for the first time. An explosion ensued. Cause not understood. *MCA Case History* **949** (1963).
Carbon Disulfide	See CARBON DISULFIDE plus Azides.
Copper	See COPPER plus Lead Azide.
Zinc	See COPPER plus Lead Azide.

LEAD CARBONATE $PbCO_3$

Fluorine	See FLUORINE plus Carbonates and FLUORINE plus Lead Carbonate (Basic).

LEAD CARBONATE (BASIC) $2PbCO_3 \cdot Pb(OH)_2$

Fluorine	See FLUORINE plus Lead Carbonate (Basic) and FLUORINE plus Carbonates.

LEAD CHLORATE $Pb(ClO_3)_3$

Sulfur	See SULFUR plus Lead Chlorate.

LEAD CHLORITE $Pb(ClO_2)_2$

(self-reactive)	Lead chlorite has detonator properties but its behavior is somewhat unpredictable.
	Mellor **2, Supp. 1:** 574 (1956).
Sulfur	See SULFUR plus Lead Chlorite.

LEAD CHROMATE $PbCrO_4$

Ferric Ferrocyanide	While these two chemicals were being ground together in a ball mill to form chrome green, a spark initiated a reaction that produced a fierce fire in the pigment.
	Chem. Process (Chicago) **30:** 118 (August 1967)

LEAD CYANIDE $Pb(CN)_2$

Magnesium	See MAGNESIUM plus Cadmium Cyanide.

LEAD DIOXIDE PbO_2

(See also LEAD OXIDE)

Aluminum Carbide	See ALUMINUM CARBIDE plus Lead Peroxide.
Barium Sulfide	See BARIUM SULFIDE plus Lead Dioxide.
Boron	See BORON plus Lead Dioxide.
Calcium Sulfide	See BARIUM SULFIDE plus Lead Dioxide.
Cesium Acetylene	See CESIUM ACETYLENE CARBIDE plus

Carbide	Cupric Oxide.
Chlorine Trifluoride	See CHLORINE TRIFLUORIDE plus Aluminum Oxide.
Hydrogen Peroxide	Hydrogen peroxide reacts violently with lead dioxide, lead monoxide, mercuric oxide, potassium, and sodium.
	Mellor **1:** 937 (1946-1947).
Hydrogen Sulfide	When hydrogen sulfide is passed over moist or dry lead dioxide, the mass becomes red-hot, producing a blue flame.
	Mellor **7:** 689 (1946-1947).
Hydroxylamine	A mixture of hydroxylamine with barium dioxide or lead dioxide ignites.
	Mellor **8:** 291 (1946-1947).
Molybdenum	See MOLYBDENUM plus Lead Dioxide.
Performic Acid	See PERFORMIC ACID plus Lead Dioxide.
Phenyl Hydrazine	Lead dioxide reacts instantly and vigorously with phenyl hydrazine.
	Mellor **7:** 637 (1946-1947).
Phosphorus	See PHOSPHORUS plus Lead Dioxide.
Phosphorus Trichloride	When lead dioxide is added to warm phosphorus trichloride, the mixture becomes incandescent.
	Mellor **7:** 690 (1946-1947).
Sulfur	See SULFUR plus Lead Dioxide.
Sulfuryl Chloride	See SULFURYL CHLORIDE plus Lead Dioxide.
Tungsten	See MOLYBDENUM plus Lead Dioxide.
Zirconium	See ZIRCONIUM plus Cupric Oxide.

LEAD FLUORIDE PbF_2

Calcium Carbide	See CALCIUM CARBIDE plus Lead Fluoride.
Fluorine	See FLUORINE plus Lead Fluoride.

LEAD HYPOPHOSPHITE $Pb(PH_2O_2)_2$

(self-reactive)	Lead hypophosphite forms impact-sensitive ammunition-priming mixtures. *Mellor* **8, Supp. 3:** 623 (1971).
Lead Nitrate	This mixture forms a highly explosive double salt with rate of detonation greater than that of mercury fulminate. *Mellor* **8:** 887 (1946-1947).

LEAD IMIDE PbNH

Acids	See LEAD IMIDE plus Water.
Water	Lead imide explodes when heated or when treated with water or dilute acids. *Mellor* **8:** 265 (1946-1947).

LEAD MONOXIDE PbO

Hydrogen Peroxide	See LEAD DIOXIDE plus Hydrogen Peroxide.
Lithium Carbide	See LITHIUM CARBIDE plus Lead Monoxide.

LEAD NITRATE $Pb(NO_3)_2$

Ammonium Thiocyanate	See AMMONIUM THIOCYANATE plus Lead Nitrate.
Carbon	See CARBON plus Lead Nitrate.
Lead Hypophosphite	See LEAD HYPOPHOSPHITE plus Lead Nitrate.

LEAD OXIDE PbO; PbO_2; Pb_2O_3; Pb_3O_4

(See also LEAD DIOXIDE)

Aluminum	See ALUMINUM plus Lead Oxide.
Cesium Acetylene	See CESIUM ACETYLENE CARBIDE plus

Carbide	Cupric Oxide.
Fluorine and Glycerol	See FLUORINE plus Lead Oxide and Glycerol.
Hydrogen Trisulfide	See HYDROGEN TRISULFIDE plus Lead Oxide.
Perchloric Acid and	Over a period of time, perchloric acid fumes
Glycerine	from a laboratory hood condensed on the cover plate of the exhaust fan, which was sealed with a cement of glycerine and litharge (lead monoxide). When a workman tapped the plate with a chisel, a violent explosion caused two injuries and one fatality.
	Serious Acc. Series **184** (1962).
Rubidium Acetylene	See RUBIDIUM ACETYLENE CARBIDE
Carbide	plus Lead Oxide.
Rubidium Carbide	See RUBIDIUM CARBIDE plus Lead Oxide.
Silicon and Aluminum	See SILICON plus Aluminum and Lead Oxide.
Sodium	See SODIUM plus Lead Oxide.
Sulfur Trioxide	The reaction between sulfur trioxide and lead oxide is attended by white luminescence.
	Mellor **7:** 654 (1946-1947).
Titanium	See TITANIUM plus Cupric Oxide.
Zirconium	See ZIRCONIUM plus Cupric Oxide.

LEAD OXYCHLORIDE Pb_2OCl_2

Potassium	See POTASSIUM plus Boric Acid.

LEAD PERCHLORATE $Pb(ClO_4)_2$

Methyl Alcohol	A flask containing a saturated solution of anhydrous lead perchlorate dissolved in methyl alcohol exploded when it was disturbed.
	ACS **146:** 209. *J. Am. Chem. Soc.* **52:** 2391-6 (1930).

LEAD PEROXIDE PbO_2

(See LEAD DIOXIDE)

Potassium	See POTASSIUM plus Boric Acid.

LEAD PHOSPHITE $Pb(H_2PO_3)_2$

(self-reactive)	A fiber drum of lead diphosphite caught fire apparently without any external cause. Since phosphite salts decompose rapidly at elevated temperatures (200¡ C), it is believed a gradual decomposition took place, yielding lead phosphate, water, and phosphine. Phosphine, in turn, is spontaneously flammable in air and was the probable secondary cause of the fire. *Schwab* (1967). *Kirk and Othmer* **10:** 489 (1947).

LEAD STYPHNATE $PbO_2C_6H(NO_2)_3$

(self-reactive)	This compound is a weak but highly sensitive explosive. *Urbanski,* Vol. III, p. 213 (1967). An employee was removing a beaker of lead styphnate from a laboratory oven when he apparently bumped the beaker on the side of the oven. A detonation occurred. *MCA Case History* **957** (1966). Three kilograms of lead styphnate detonated from an unknown cause in the anteroom of a dry-house. Wet material in two adjacent drying rooms did not detonate. *Chem. Abst.* **26:** 5210 (1932).

LEAD SULFATE $PbSO_4$

Potassium	See POTASSIUM plus Boric Acid.

LEAD SULFIDE PbS

Iodine Monochloride	See IODINE MONOCHLORIDE plus Cadmium Sulfide.
Hydrogen Peroxide	See ANTIMONY TRISULFIDE plus Hydrogen Peroxide.

LEAD TETRAAZIDE $Pb(N_3)_4$

(self-reactive)	Lead tetraazide is too unstable to be isolated. The ammonium double salt is an unstable explosive compound.
	Mellor **8, Supp. 2:** 22 (1967).

LEAD TRINITRORESORCINATE $Pb\ O_2C_6H(NO_2)_3$

(See LEAD STYPHNATE)

LEWIS-TYPE CATALYSTS

Allyl Chloride	See SULFURIC ACID plus Allyl Chloride.

LIMESTONE (CRUSHED)

Fluorine	See FLUORINE plus Common Materials and Oxygen.

LIMONENE $C_{10}H_{16}$

Iodine Pentafluoride and Tetrafluoroethylene	See IODINE PENTAFLUORIDE plus Tetrafluoroethylene and Limonene.

LINSEED OIL

Chlorine	See CHLORINE plus Polypropylene.

LITHIUM Li

Air	Lithium is spontaneously flammable in air if heated to 180¡C., if the surface of the metal is clean. See also LITHIUM plus Oxygen.

	Mellor **2:** 468 (1946-1947).
Arsenic	The reaction of lithium is violent with both strongly heated arsenic and phosphorus.
	Mellor **2, Supp. 1:** 77 (1956).
Beryllium	See LITHIUM plus Vanadium.
Bromine	See BROMINE plus Potassium.
Bromoform	Lithium mixed with the following compounds can explode on impact: bromoform, carbon tetrabromide, chloroform, iodoform, methyl dichloride, and methyl diiodide.
	Mellor **2, Supp. 2:** 83 (1961).
Carbides	Molten lithium attacks carbides and silicates.
	Mellor **2, Supp. 2:** 84 (1961).
Carbon Dioxide	See LITHIUM plus Oxygen.
	See also LITHIUM Plus Water.
Carbon Monoxide	The product of the reaction between lithium
and Water	and carbon monoxide, lithium carbonyl, detonates violently with water, igniting gaseous products.
	Mellor **2, Supp. 2:** 88 (1961).
Carbon Tetrabromide	See LITHIUM plus Bromoform.
Carbon Tetrachloride	There was no reaction when a drop or two of carbon tetrachloride was added to burning lithium. When the quantity was eventually increased to about 25 cc of carbon tetrachloride, a violent explosion occurred.
	Allison (1968).
	See also LITHIUM plus Trichlorotrifluoroethane.
	A billet-cutting knife initiated a violently explosive reaction between lithium and carbon tetrachloride.
	Mellor **2, Supp. 2:** (1961).
	See also LITHIUM plus Water.
Chlorine	See CESIUM plus Chlorine.
Chloroform	Chloroform with various alkali metals is impact-sensitive

	as follows: weak explosion with lithium; fairly strong with sodium; strong with potassium; and violent with sodium-potassium.
	H. Staudinger, *Z. Electrochem.* **31:** 549-52 (1925).
	See LITHIUM plus Bromoform.
Chromic Oxide	The reaction of lithium and chromic oxide occurs around 180¡ C with consequent temperature rise to 965¡ C.
	Mellor **2, Supp. 2:** 81 (1961).
Chromium	See LITHIUM plus Vanadium.
Chromium Trichloride	On dusting a lithium strip with either chromium trichloride or zirconium tetrachloride then warming in a nitrogen atmosphere, the lithium burns vigorously, presumably forming lithium nitride.
	BCISC **40** (158): 17 (1968).
Cobalt Alloys	Molten lithium attacks the following alloys: cobalt alloys, iron alloys, manganese alloys, nickel alloys.
	Mellor **2, Supp. 2:** 80 (1961).
Diborane	See ALUMINUM plus Diborane.
Ferrous Sulfide	The reaction of lithium and ferrous sulfide occurs around 260¡ C with consequent temperature rise to 945¡ C.
	Mellor **2, Supp. 2:** 82 (1961).
Halogenated Hydrocarbons	See LITHIUM plus Oxygen.
Hydrogen	Lithium burns in gaseous hydrogen.
	Mellor **1:** 327 (1946-1947).
Iodine	See IODINE plus Lithium.
Iodoform	See LITHIUM plus Bromoform.
Iron Alloys	See LITHIUM plus Cobalt Alloys.
Maleic Anhydride	See ALKALI METALS plus Maleic Anhydride.
Manganese Alloys	See LITHIUM plus Cobalt Alloys.

Methyl Dichloride	See LITHIUM plus Bromoform.
Methyl Diiodide	See LITHIUM plus Bromoform.
Molybdenum Trioxide	The reaction of lithium and molybdenum trioxide occurs at about 180¡ C with consequent temperature rise to 1400¡ C. *Mellor* **2, Supp. 2:** 82 (1961).
Monofluorotrichloromethane	See LITHIUM plus Trichlorotrifluoroethane.
Nickel Alloys	See LITHIUM plus Cobalt Alloys.
Niobium Pentoxide	The reaction of lithium and niobium pentoxide occurs around 320¡ C, with consequent temperature rise to 490¡ C. *Mellor* **2, Supp. 2:** 81 (1961).
Nitric Acid	When 15 ml. of nitric acid were poured onto 15 grams of lithium in an attempt to dissolve the metal, a small fire started in the flask. In less than a minute, the reaction was so vigorous that burning lithium was thrown upward in the laboratory hood. *Acc. and Fire Prev. Inf.* (March 31, 1954).
Nitrogen	See LITHIUM plus Oxygen; also LITHIUM plus Trichlorotrifluoroethane. The reaction of lithium and nitrogen increases greatly as the metal melts. *Mellor* **2, Supp. 2:** 77 (1961).
Organic Matter	Molten lithium attacks plastics and rubber. *Mellor* **2, Supp. 2:** 84 (1961).
Oxygen	Lithium will burn in air, oxygen, nitrogen, and carbon dioxide. The susceptibility of molten lithium surfaces to spontaneous ignition is increased by the presence of lithium oxides or nitrides. These reactions and the reaction with water are extremely violent at higher temperatures. Contact with halogenated hydrocarbons can produce extremely violent reactions, especially on impact. *ASESB Pot. Incid.* **39** (1968). *Haz. Chem. Data* (1966).
Phosphorus	See LITHIUM plus Arsenic.

	See PHOSPHORUS plus Cesium.
Platinum	Platinum and molten lithium react violently at 540¡ C plus or minus 20¡. An intermetallic compound is formed.
	Chem. Eng. News **39** (5): 42 (January 30, 1961).
Rubber	See LITHIUM plus Organic Matter.
Silicates	See LITHIUM plus Carbides.
Sodium Chloride	Sodium chloride extinguishant should not be used on lithium fires since the reaction releases sodium and results in a more violent fire.
	Fatt and Tashima, p. 32.
Sodium Nitrite	Lithium reacts with sodium nitrite to form lithium sodium hydronitrite, a compound which decomposes violently around 100¡-130¡ C.
	Mellor **2, Supp. 2:** 78 (1961).
Sulfur	The reaction of lithium and sulfur is very violent when either is molten, starting with explosive violence.
	Mellor **2, Supp. 2:** 74 (1961).
Tantalum Pentoxide	The reaction of lithium and tantalum pentoxide occurs around 410¡ C with consequent temperature rise to 595¡ C.
	Mellor **2, Supp. 2:** 81 (1961).
Tetrachloroethylene	See LITHIUM plus Trichlorotrifluoroethane.
Titanium Dioxide	The reaction of lithium and titanium dioxide occurs around 200¡ C with a flash of light; the temperature can reach 900¡ C.
	Mellor **2, Supp. 2:** 81 (1961).
Trichloroethylene	See LITHIUM plus Trichlorotrifluoroethane.
Trichlorotrifluoroethane	It has been determined experimentally that mixtures of lithium shavings and a number of halogenated hydrocarbons possess an explosive capability. Specifically, impact sensitivity tests have shown that lithium shavings in contact with monofluorotrichloromethane, trichlorotrifluoroethane, carbon tetrachloride, trichloroethylene, or tetrachloroethylene can detonate.

	ASESB Pot. Incid. **39** (1968).
Tungsten Trioxide	The reaction of lithium and tungsten trioxide occurs at about 200¡ C with consequent temperature rise to 1030¡ C.
	Mellor **2, Supp. 2:** 82 (1961).
Vanadium	Molten lithium at 180¡ C attacks vanadium, beryllium, or chromium severely.
	Mellor **2, Supp. 2:** 80 (1961).
Vanadium Pentoxide	The reaction of lithium and vanadium pentoxide occurs around 400¡ C; the temperature then rises rapidly to 768¡ C.
	Mellor **2, Supp. 2:** 81 (1961).
Water	See LITHIUM plus Oxygen.
	Liquid lithium is readily ignited and reacts with most extinguishing agents, including water, carbon tetrachloride and carbon dioxide.
	Mellor **2, Supp. 2:** 71 (1961).
Zirconium Tetrachloride	See LITHIUM plus Chromium Trichloride.

LITHIUM ACETYLENE CARBIDE DIAMMINO $LiC{\equiv}CHNH_3$

Carbon Dioxide	Lithium acetylene carbide diammino burns on contact with carbon dioxide, chlorine, sulfur dioxide, and water.
	Mellor **5:** 849 (1946-1947).
Chlorine	See LITHIUM ACETYLENE CARBIDE DIAMMINO plus Carbon Dioxide.
Sulfur Dioxide	See LITHIUM ACETYLENE CARBIDE DIAMMINO plus Carbon Dioxide.
Water	See LITHIUM ACETYLENE CARBIDE DIAMMINO plus Carbon Dioxide.

LITHIUM ALUMINUM HYDRIDE

(See LITHIUM TETRAHYDROALUMINATE)

LITHIUM AMIDE $LiNH_2$

Water	Lithium amide reacts readily with water and develops a dangerous amount of heat. *Chaney* (1948). *Chapman* (1948). F. W. Bergstrom and W. C. Fernelius, *Chem. Reviews* **12:** 61 (1933).

LITHIUM AZIDE LiN_3

Carbon Disulfide	See AZIDES plus Carbon Disulfide.

LITHIUM BOROHYDRIDE

(See LITHIUM TETRAHYDROBORATE)

LITHIUM BUTYL LiC_4H_9

(See BUTYL LITHIUM)

LITHIUM CARBIDE Li_2C_2

Bromine	See BROMINE plus Lithium Carbide.
Chlorine	See BROMINE plus Lithium Carbide.
Fluorine	See BROMINE plus Lithium Carbide.
Iodine	See BROMINE plus Lithium Carbide. See IODINE plus Cesium Carbide.
Lead Monoxide	Lithium carbide in the presence of lead monoxide is reduced with great vigor and with incandescence. *Mellor* **5:** 849 (1946-1947).
Phosphorus	See PHOSPHORUS plus Lithium Carbide.
Selenium	See SULFUR plus Lithium Carbide.
Sulfur	See SULFUR plus Lithium Carbide.

LITHIUM CARBONATE Li_2CO_3

Fluorine	See FLUORINE plus Carbonates.

LITHIUM CARBONYL LiCOCOLi

(self-reactive)	See LITHIUM plus Carbon Monoxide and Water.

LITHIUM CHLORIDE LiCl

Bromine Trifluoride	See BROMINE TRIFLUORIDE plus Barium Chloride.

LITHIUM ETHYL C_2H_5Li

(See ETHYL LITHIUM)

LITHIUM HEXAPHENYLTUNGSTATE ETHERATE

$Li_3W(C_6H_5)_63(C_2H_5)_2O$

Air	Triphenyl tungsten-tris(phenyl lithium)-tri (diethyl ether) is spontaneously flammable in air. *Douda* (1966).

LITHIUM HYDRIDE LiH

Nitrous Oxide	See NITROUS OXIDE plus Lithium Hydride.
Oxygen (Liquid)	See OXYGEN (LIQUID) plus Lithium Hydride.

LITHIUM METHYL

(See METHYL-LITHIUM)

LITHIUM METHYLIDE CH_2Li_2

Air	Methylene dilithium is spontaneously flammable in air.
	Douda (1966).

LITHIUM PHENYL C_6H_5Li

(See PHENYL LITHIUM)

LITHIUM PHENYLAZOXIDE $LiON{=}NC_6H_5$

(self-reactive)	See PHENYL-LITHIUM plus Nitrous Oxide.

LITHIUM PHOSPHIDE Li_3P

Water	Lithium phosphide reacts with water to form spontaneously flammable phosphine.
	Van Wazer (1958).

LITHIUM PROPYL C_3H_7Li

(See PROPYL LITHIUM)

LITHIUM SILICIDE Li_6Si_2

Bromine	See FLUORINE plus Lithium Silicide.
Fluorine	See FLUORINE plus Lithium Silicide.
Hydrogen Chloride	Lithium silicide in contact with hydrogen chloride becomes incandescent. When dilute hydrochloric acid is used, a gas spontaneously flammable in air is evolved.
	Mellor **6:** 170 (1946-1947).
Nitric Acid	Lithium silicide reacts explosively with nitric acid, producing nitrogen dioxide and silica.
	Mellor **6:** 170 (1946-1947).
Phosphorus	See PHOSPHORUS plus Lithium Silicide.

Selenium	See PHOSPHORUS plus Lithium Silicide.
Sulfuric Acid	When lithium silicide is placed on sulfuric acid, it becomes incandescent.
	Mellor **6:** 170 (1946-1947).
Tellurium	See PHOSPHORUS plus Lithium Silicide.
Water	The reaction between lithium silicide and water is very violent; a spontaneously flammable gas is evolved.
	Mellor **6:** 170 (1946-1947).

LITHIUM SODIUM HYDRONITRITE

(See LITHIUM plus Sodium Nitrite)

LITHIUM TETRAAZIDOBORATE $LiB(N_3)_4$

(self-reactive)	See BORON TRIAZIDE (self-reactive)

LITHIUM TETRAHYDROALUMINATE $LiAlH_4$

Air	Lithium aluminum hydride can burn in heated or moist air.
	Haz. Chem. Data, p. 101 (1966).
	Lab. Govt. Chemist (1965).
Alcohols	See LITHIUM ALUMINUM HYDRIDE plus Water.
Acids	See LITHIUM ALUMINUM HYDRIDE plus Water.
Benzoyl Peroxide	See BENZOYL PEROXIDE plus Lithium Aluminum Hydride.
Boron Trifluoride Etherate	In a laboratory effort to prepare diborane gas from these reactants, the boron trifluoride etherate in ether was frozen at liquid nitrogen temperature, lumps of lithium aluminum hydride were added, and the system was evacuated. Because of insufficient vacuum, the connection between the apparatus and the vacuum source was reopened. When this action jarred the reaction flask, an explosion and orange flame resulted. The presence of

	oxides in the etherate probably initiated the reaction.
	Chem. Eng. News **45** (20): 51 (1967); **45** (27): **7** (1967).
2-Chloromethylfuran and Ethyl Acetate	See 2-CHLOROMETHYLFURAN plus Lithium Aluminum Hydride and Ethyl Acetate.
Diethylene Glycol Dimethyl Ether	A violent explosion occurred when lithium aluminum hydride was being used to dry diethylene glycol dimethyl ether. About 75 per cent of the ether had been distilled when the explosion occurred.
	R. M. Adams, *Chem. Eng. News* **31:**2334 (1953).
	MCA Case History **1494** (1968).
Diethyl Ether	With aluminum chloride as a catalyst, occasional explosions involving these materials have been traced to carbon dioxide as an impurity in the ether.
	J. Am. Chem. Soc. **70:** 877 (1948).
1,2-Dimethoxyethane	When the solvent, dimethoxyethane was poured into a funnel previously used to introduce the hydride into a reaction flask, a fire ignited in the funnel.
	MCA Case History **1182** (1966).
Dimethyl Ether	Use of lithium aluminum hydride to dry methyl ethers may cause explosions, which are attributed to solubility of carbon dioxide. High concentrations of peroxides were found to be present.
	MCA Guide for Safety, Appendix 3 (1972).
Methyl Ethyl Ether	See LITHIUM ALUMINUM HYDRIDE plus Dimethyl Ether.
Nitriles and Water	The nitrile reaction with an ether solution of the hydride was conducted in a flask equipped with a reflux condenser having a drying tube. After the apparatus had stood over the weekend, moisture worked back into the flask through the ground glass joint. The lubricant had evidently been dissolved by the ether. When the moisture reached the reactants in the flask an explosion resulted.
	NSC Newsletter, *Chem. Sec.* (April 1967).
Perfluorosuccinamide	Perfluorosuccinamide was added to an ether solution of

	lithium aluminum hydride in a nitrogen atmosphere. Hydrolysis was then attempted but as the second drop of water was added, a violent explosion occurred.
	MCA Guide for Safety, Appendix 3 (1972).
Perfluorosuccinamide and Water	Perfluorosuccinamide was added to an ether solution of lithium aluminum hydride in an atmosphere of nitrogen. When hydrolysis of the mixture was attempted, a violent explosion and fire occurred after the second drop of water was added.
	T.S. Reid and G.H. Smith, *Chem. Eng. News* **29:** 3042 (1951).
Tetrahydrofuran	See TETRAHYDROFURAN plus Lithium Aluminum Hydride.
Water	Lithium aluminum hydride reacts vigorously with hydroxy compounds: water, alcohols, carboxylic acids.
	Mellor **2, Supp. 2:** 142 (1961).

LITHIUM TETRAHYDROBORATE $LiBH_4$

Cellulosic Material	Lithium borohydride is likely to ignite in contact with cellulosic materials.
	Lab. Govt. Chemist (1965).
Water	Lithium borohydride is likely to ignite when moistened with water.
	Lab. Govt. Chemist (1965). *Gaylord*, p. 22 (1956).

LITHIUM TETRAMETHYLBORATE $LiB(CH_3)_4$

Water	Lithium tetramethyl borate may ignite spontaneously in moist air.
	Dreisback, pp. 93-94 (1961).

LITHIUM TRI-tert-BUTOXYALUMINATE

$LiAl(OC(CH_3)_3)_3H$

Water	Lithium aluminum tri-tert-butoxyhydride reacts with water to form hydrogen. Ignition sometimes occurs.
	Rose (1961).

LUCITE□

Fluorine	See FLUORINE plus Solid Nonmetals and Oxygen.

LUTETIUM Lu

Air	See RARE EARTH METALS plus Air.
Halogens	See RARE EARTH METALS plus Halogens.

MAGNESIUM Mg

Air	Magnesium ribbon and fine magnesium shavings can be ignited at air temperatures of about 950¡ F and very finely divided magnesium powder has been ignited at air temperatures below 900¡ F.
	Magnesium Standard, p. 4 (1967).
Aluminum and	See ALUMINUM plus Magnesium and Potassium
Potassium Perchlorate	Perchlorate.
Ammonium Nitrate	See AMMONIUM NITRATE plus Metals (powdered).
Barium Nitrate,	A mixture consisting of barium dioxide,
Barium Dioxide	barium nitrate, magnesium and zinc exploded
and Zinc	from an unknown cause, demolishing a small plant.
	Sprengstoffe, Waffen u. Munitions (1905).
Beryllium Oxide	Oxides of beryllium, cadmium, mercury, molybdenum and zinc can react explosively with magnesium when heated.
	Mellor **4:** 272 (1946-1947).
Boron Phosphodiiodide	Powdered magnesium and boron phosphodiiodide react

	with incandescence.
	Mellor **8:** 845 (1946-1947).
Bromobenzyl Trifluoride	Bromobenzyl trifluoride was added to magnesium turnings in sodium-dried ether at a rate so as to maintain reflux. After a period of time an explosion occurred.
	MCA Case History **1834** (1972).
Cadmium Cyanide	Magnesium reacts with incandescence when heated with cyanides of cadmium, cobalt, copper, lead, nickel, or zinc.
	Mellor **4:** 271 (1946-1947).
Cadmium Oxide	See MAGNESIUM plus Beryllium Oxide.
Calcium Carbide	Magnesium reacts with incandescence when heated in air with calcium carbide.
	Mellor **4:** 271 (1946-1947).
Carbonates	A mixture of the two may cause an explosion.
	Pieters, p. 30 (1957).
Carbon Tetrachloride	See MAGNESIUM plus Trichloroethylene; also ALUMINUM plus Chloroform.
Chlorine	Magnesium exposed to moist chlorine is spontaneously flammable.
	Mellor **4:** 267 (1946-1947).
Chlorine Trifluoride	See ALUMINUM plus Chlorine Trifluoride.
Chloroform	When chloroform or methyl chloride (or mixtures of both) contacts magnesium, an explosion occurs.
	C.C. Clogston, *UL Bull. Research* **34:** 15 (1945).
Cobalt Cyanide	See MAGNESIUM plus Cadmium Cyanide.
Copper Cyanide	See MAGNESIUM plus Cadmium Cyanide.
Copper Sulfate (anhydrous), Ammonium Nitrate,	The water permits both the exothermic reaction of $Mg+Cu^{++}$ to give $Cu+Mg^{++}$ and the metathetical reaction of the salts, which

Potassium Chlorate	produces the unstable ammonium chlorate.
and Water	The mixture is unstable and hazardous.
	Ellern, p. 46 (1968).
Cupric Oxide	The reduction of heated cupric oxide by admixed magnesium is accompanied by incandescence and an explosion.
	Mellor **3:** 138 (1946-1947).
Cupric Sulfate	The action of magnesium on a solution of cupric sulfate is attended by the evolution of hydrogen.
	Mellor **3:** 247 (1946-1947).
Fluorine	Magnesium exposed to moist fluorine is spontaneously flammable.
	Mellor **4:** 267 (1946-1947).
Gold Cyanide	Cyanides of gold or mercury decompose to the metals and cyanogen. The latter reacts explosively with magnesium.
	Mellor **4:** 271 (1946-1947).
Hydrogen and	When a mixture of magnesium and calcium
Calcium Carbonate	carbonate is heated in a current of hydrogen, a violent explosion occurs.
	Mellor **4:** 272 (1946-1947).
Hydrogen Iodide	Magnesium burns momentarily in hydrogen iodide.
	Mellor **2:** 206 (1946-1947).
Hydrogen Peroxide	Magnesium mixed with a trace of manganese dioxide ignites immediately in contact with hydrogen peroxide.
	Mellor **1:** 938 (1946-1947).
Iodine	Magnesium burns vigorously when heated in iodine vapor.
	Mellor **4:** 267 (1946-1947).
Lead Cyanide	See MAGNESIUM plus Cadmium Cyanide.
Mercuric Oxide	See MAGNESIUM plus Beryllium Oxide.
Mercury Cyanide	See MAGNESIUM plus Gold Cyanide.

Methyl Chloride	See MAGNESIUM plus Chloroform.
Molybdenum Trioxide	When molybdenum trioxide is heated with molten magnesium, a violent detonation occurs.
	H.N. Warren, *Chem. News* **64:** 75 (1891).
	See MAGNESIUM plus Beryllium Oxide.
Nickel Cyanide	See MAGNESIUM plus Cadmium Cyanide.
Nitric Acid	A mixture of finely divided magnesium and nitric acid is explosive.
	Pieters, p. 28 (1957).
Nitrogen Dioxide	Magnesium, phosphorus or sulfur burns vigorously in nitrogen dioxide.
	Comp. Rend. **116:** 756
Oxygen (Liquid)	*Liquid* oxygen (LOX) gives a detonable mixture when combined with *powdered* magnesium.
	Kirschenbaum (1956).
Performic Acid	Powdered magnesium can decompose performic acid violently.
	Berichte **48:** 1139 (1915).
Phosphates	A mixture of the two may cause an explosion.
	Pieters, p. 30 (1957).
Potassium Chlorate	An explosion occurred during heating of a mixture of potassium chlorate and magnesium.
	Chem. Eng. News **14:** 451 (1936).
Potassium Perchlorate	Powdered magnesium plus potassium (or sodium) perchlorate is a friction-sensitive explosive mixture.
	V.E. Ready, *Safety Eng. Reports* (1947).
Silver Nitrate	A mixture of the two ingredients will burst into flame on moistening. The water causes electrochemical exchange between the magnesium and the silver ion. The heat of reaction of this exchange provokes the pyrochemical effect.
	Ellern, p. 46 (1968).

Silver Oxide	See SILVER OXIDE plus Magnesium.
Sodium Perchlorate	See MAGNESIUM plus Potassium Perchlorate.
Sodium Peroxide	Sodium peroxide oxidizes magnesium powder with incandescence. The mixture explodes when heated to redness. When the mixture is exposed to moist air, spontaneous combustion occurs.
	Mellor **2:** 490; **5:** 217 (1946-1947).
Sodium Peroxide and Carbon Dioxide	When carbon dioxide gas is passed over a mixture of powdered magnesium and sodium peroxide, the mixture explodes.
	Mellor **2:** 490 (1946-1947).
Stannic Oxide	Stannic oxide, heated with magnesium, explodes.
	Mellor **7:** 401 (1946-1947).
Sulfates	A mixture of the two may cause an explosion.
	Pieters, p. 30 (1957).
Trichloroethylene	It has been determined experimentally that a mixture of magnesium powder with trichloroethylene or with carbon tetrachloride will flash or spark under heavy impact.
	ASESB Pot. Incid. **39** (1968).
Zinc Cyanide	See MAGNESIUM plus Cadmium Cyanide.
Zinc Oxide	See MAGNESIUM plus Beryllium Oxide.

MAGNESIUM ALLOYS

Air	Magnesium alloy powders containing more than 50% magnesium readily ignite in air.
	Lab. Govt. Chemist (1965).
	Magnesium Standard, p. 5 (1967).

MAGNESIUM ALUMINUM PHOSPHIDE Mg_3AlP_3

Water	In contact with water or damp air, magnesium aluminum

	phosphide evolves phosphine, which is spontaneously flammable in air.
	Lab. Govt. Chemist (1965).

MAGNESIUM BORIDE Mg_3B_2

Hydrochloric Acid	Magnesium boride, when treated with concentrated hydrochloric acid, produces a spontaneously flammable gas.
	Mellor **5:** 25 (1946-1947).

MAGNESIUM BROMATE $Mg(BrO_3)_2$

Aluminum	See ALUMINUM plus Bromates.
Arsenic	See ARSENIC plus Bromates.
Carbon	See CARBON plus Bromates.
Copper	See COPPER plus Bromates.
Metal Sulfides	See METAL SULFIDES plus Bromates.
Organic Matter	See BROMATES plus Organic Matter.
Phosphorus	See PHOSPHORUS plus Bromates.
Sulfur	See SULFUR plus Bromates.

MAGNESIUM CHLORATE $Mg(ClO_3)_2$

Aluminum	See ALUMINUM plus Bromates.
Antimony Sulfide	See CHLORATES plus Antimony Sulfide.
	See METAL SULFIDES plus Bromates.
Arsenic	See ARSENIC plus Bromates.
Arsenic Sulfide	See CHLORATES plus Arsenic Sulfide. See METAL SULFIDES plus Bromates.
Carbon	See CARBON plus Bromates.

Charcoal	See CHLORATES plus Organic Matter.
Copper	See COPPER plus Bromates.
Copper Sulfide	See COPPER SULFIDE plus Cadmium Chlorate.
Manganese Dioxide	See CHLORATES plus Manganese Dioxide.
Metal Sulfides	See METAL SULFIDES plus Bromates.
Organic Acids (Dibasic)	See CHLORATES plus Organic Acids.
Organic Matter	See BROMATES plus Organic Matter. See CHLORATES plus Organic Matter.
Phosphorus	See PHOSPHORUS plus Bromates.
Stannic Sulfide	See STANNIC SULFIDE plus Cadmium Chlorate. See METAL SULFIDES plus Bromates.
Stannous Sulfide	See STANNIC SULFIDE plus Cadmium Chlorate.
	See METAL SULFIDES plus Bromates.
Sulfur	See SULFUR plus Bromates. See CHLORATES plus Organic Matter.

MAGNESIUM CHLORIDE MgCl

2-Furan Percarboxylic Acid	See 2-FURAN PERCARBOXYLIC ACID (self-reactive).

MAGNESIUM DIBUTYL $(C_4H_9)Mg$

(See DIBUTYL MAGNESIUM)

MAGNESIUM DIETHYL $(C_2H_5)_2Mg$

(See DIETHYL MAGNESIUM)

MAGNESIUM DIMETHYL $(CH_3)_2Mg$

(See DIMETHYL MAGNESIUM)

MAGNESIUM HYDRIDE MgH_2

Air	Magnesium hydride ignites spontaneously in air.
	Merck Index, p. 637 (1968).
Water	Magnesium hydride ignites violently with water.
	Merck Index, p. 637 (1968).

MAGNESIUM HYDROXIDE $Mg(OH)_2$

Maleic Anhydride	See SODIUM HYDROXIDE plus Maleic Anhydride.
Phosphorus	See PHOSPHORUS plus Alkaline Hydroxide.

MAGNESIUM HYPOPHOSPHITE $Mg(PH_2O_2)_2$

(self-reactive)	Magnesium hypophosphite liberates spontaneously flammable phosphine when heated.
	Mellor **8:** 885 (1946-1947).

MAGNESIUM IODATE $Mg(IO_3)_2$

Aluminum	See ALUMINUM plus Bromates.
Arsenic	See ARSENIC plus Bromates.
Carbon	See CARBON plus Bromates.
Copper	See COPPER plus Bromates.
Metal Sulfides	See METAL SULFIDES plus Bromates.
Organic Matter	See BROMATES plus Organic Matter.
Phosphorus	See PHOSPHORUS plus Bromates.
Sulfur	See SULFUR plus Bromates.

MAGNESIUM METHYLIDE CH_2Mg

Air	Methylene magnesium is spontaneously flammable in air.
	Coates, p. 29 (1956).

MAGNESIUM NITRATE $Mg(NO_3)_2$

Dimethyl Formamide	See DIMETHYL FORMAMIDE plus Magnesium Nitrate.

MAGNESIUM OXIDE MgO

Chlorine Trifluoride	See CHLORINE TRIFLUORIDE plus Aluminum Oxide.
Phosphorus Pentachloride	See PHOSPHORUS PENTACHLORIDE plus Magnesium Oxide.

MAGNESIUM PERCHLORATE $Mg(ClO_4)_2$

Acids (Mineral)	Magnesium perchlorate should not be contacted by mineral acids because of the danger of explosion.
	ACS **146:** 208. *Chem. Weekblad.* **38:** 85 (1941); **54:** 277 (1958). *Ind. & Eng. Chem. News* **17:** 70 (1939).
Ammonia	Magnesium perchlorate was contained in a small steel refrigeration-type drying tube and the ammonia was passed through it (after the system was evacuated) in small increments in an attempt to further desiccate it. It was noted that the outside of the drying tube was warm to the touch. Shortly thereafter the tube exploded violently.
	F.F. Chapman (1973).
Butyl Fluoride	The butyl fluoride content of hydrocarbon gases being dried by magnesium perchlorate hydrolyzed. Reaction of the acid formed with the perchlorate caused an explosion.
	ACS **146:** 208-9. *Chem. Weekblad.* **38:** 85 (1941); **54:** 277 (1958). *Ind. & Eng. Chem. News* **17:** 70 (1939).
Dimethyl Sulfoxide	See DIMETHYL SULFOXIDE plus Magnesium Perchlorate.
Ethylene Oxide	Drying gaseous ethylene oxide with magnesium perchlorate resulted in an explosion.

	NSC Newsletter, Chem. Sec. (Oct. 1959).
Hydrocarbons	Magnesium perchlorate, used in drying hydrocarbon gases, exploded when it was heated to 220¡ C.
	ACS **146:**208-9, *Chem. Weekblad.* **38:**85 (1941); **54:**277 (1958). *Ind. & Eng. Chem. News* **17:** 70 (1939).
	Magnesium perchlorate, used in drying unsaturated hydrocarbons, exploded on being heated to 220¡ C.
	P. M. Heertjes and J. P. W. Houtman, *Chem. Weekblad* **38:**85 (1941).
Organic Matter	Several instances of explosions from using magnesium perchlorate as a drying agent for organic matter have been documented.
	Chem. Eng. News **43** (37):62 (1965); **43**(47):5 (1965).
Phosphorus	See PHOSPHORUS plus Magnesium Perchlorate.
Trimethyl Phosphite	As soon as trimethyl phosphite contacted a small quantity of magnesium perchlorate in a small flask there was a brilliant flash and a loud explosion that shattered the flask.
	Allison (1968).

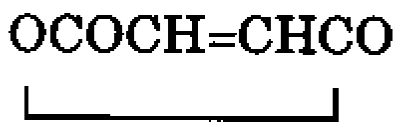
MAGNESIUM PHOSPHIDE Mg_3P_2

Bromine	See CHLORINE plus Magnesium Phosphide.
Chlorine	See CHLORINE plus Magnesium Phosphide.
Nitric Acid	Nitric acid oxidizes magnesium phosphide with incandescence.
	Mellor **8:**842 (1946-1947).
Water	Magnesium phosphide produces spontaneously flammable phosphine and diphosphine on contact with water.
	Douda (1966).

MAGNESIUM-TITANIUM ALLOY

Nitric Acid	See TITANIUM-MAGNESIUM ALLOY plus Nitric Acid.

MALEIC ANHYDRIDE



Alkali Metals	See ALKALI METALS plus Maleic Anhydride.
Amines	See SODIUM HYDROXIDE and Maleic Anhydride; also SODIUM HYDROXIDE plus Pyridine or other Tertiary Amines.
Calcium Hydroxide	See SODIUM HYDROXIDE plus Maleic Anhydride.
Lithium	See ALKALI METALS plus Maleic Anhydride.
Potassium	See ALKALI METALS plus Maleic Anhydride.
Potassium Hydroxide	See SODIUM HYDROXIDE plus Maleic Anhydride.
Pyridine or Other Tertiary Amines	A 0.1 per cent solution of pyridine in maleic anhydride at 185¡C. gives an exothermic decomposition with rapid evolution of gas.
	Chem. Eng. News **42** (8):41 (1964). *Chem. Haz. Info. Series* **C-71,** p. 5 (1960).
Sodium	See ALKALI METALS plus Maleic Anhydride.
Sodium Hydroxide	See SODIUM HYDROXIDE plus Maleic Anhydride.

MANGANESE Mn

Aluminum and Air	During a fire in an industrial bag filter, a mixture of aluminum and manganese dusts was inadvertently released from the hopper below the bag and a drastic explosion resulted.
	Occ. Haz. **28:**44-6 (November 1966).
Chlorine	Heated manganese ignites in chlorine and burns brilliantly. Powdered manganese ignites in chlorine and burns brilliantly.

	Mellor **12:**185-7 (1946-1947).
Fluorine	When powdered manganese is exposed to fluorine, the reaction takes place with incandescence.
	Mellor **12:**344 (1946-1947).
Hydrogen Peroxide	See IRON plus Hydrogen Peroxide.
Nitric Acid	Concentrated nitric acid reacts with powdered manganese with incandescence and a feeble explosion.
	Mellor **12:**188 (1946-1947).
Nitrogen Dioxide	Manganese or potassium ignites in nitrogen dioxide.
	Ann. Chim. et Phys. (2) **2:**317.
Phosphorus	When manganese is heated in the vapor of phosphorus at a very dull red heat, union occurs with incandescence.
	Mellor **8:**853 (1946-1947).
Sulfur Dioxide	Pyrophoric manganese burns with a brilliant flame when heated in sulfur dioxide vapor.
	Mellor **12:**187 (1946-1947).

MANGANESE ALLOYS

Lithium	See LITHIUM plus Cobalt Alloys.

MANGANESE ALUMINOHYDRIDE

(See MANGANOUS TETRAHYDROALUMINATE)

MANGANESE DIMETHYL $(CH_3)_2Mn$

(See DIMETHYL MANGANESE)

MANGANESE DIOXIDE MnO_2

Chlorates	See CHLORATES plus Manganese Dioxide.
Chlorine Trifluoride	Chlorine trifluoride reacts with manganese dioxide with

	incandescence.
	Mellor **12:**254 (1946-1947).
	See also CHLORINE TRIFLUORIDE plus Aluminum Oxide.
Hydrogen Peroxide	Powdered manganese dioxide dropped into a concentrated solution of hydrogen peroxide may cause an explosion.
	Mellor **1:**936, 938 (1946-1947).
Permonosulfuric Acid	See PERMONOSULFURIC ACID plus Manganese Dioxide. See PLATINUM plus Permonosulfuric Acid.
Potassium Azide	When manganese dioxide is gently heated with potassium azide the reaction is very violent.
	Mellor **8:**347 (1946-1947).
Rubidium Acetylene	See RUBIDIUM ACETYLENE CARBIDE
Carbide	plus Manganese Dioxide.
Sodium Peroxide	See SODIUM PEROXIDE plus Manganese Dioxide.

MANGANESE HEPTOXIDE Mn_2O_7

(self-reactive)	About three cubic centimeters of manganese heptoxide, stored in a brown glass bottle, exploded 5 or 6 hours after its preparation from sulfuric acid and potassium permanganate.
	Delhez (1967).
Organic Matter	When these materials are mixed, explosions may result.
	A. M. Patterson, *Chem. Eng. News* **26:**711 (1948). J. R. Archer, *Chem. Eng. News* **26:**205 (1948).
	See also POTASSIUM PERMANGANATE plus Sulfuric Acid.

MANGANESE TRIFLUORIDE MnF_3

Glass	When manganese trifluoride is heated in a glass vessel, there is a violent reaction involving the silicon in the glass,

	since silicon tetrafluoride is released.
	Mellor **12:**344 (1946-1947).

MANGANOCENE $Mn(C_5H_5)_2$

Air	Biscyclopentadienyl manganese is spontaneously flammable in air.
	Douda (1966).

MANGANOUS BROMIDE $MnBr_2$

Potassium	See POTASSIUM plus Ammonium Bromide.

MANGANOUS CHLORIDE $MnCl_2$

Potassium	See POTASSIUM plus Aluminum Bromide.
Sodium	See SODIUM plus Ferrous Chloride.
Zinc	See ZINC plus Manganese Chloride.

MANGANOUS HYPOPHOSPHITE $Mn(PH_2O_2)_2$

(self-reactive)	Manganous hypophosphite detonates above 200¡ C.
	Mellor **8:**889 (1946-1947).

MANGANOUS IODATE $Mn(IO_3)_3$

Bromine Trifluoride	See BROMINE TRIFLUORIDE plus Bismuth Pentoxide.

MANGANOUS IODIDE MnI_2

Potassium	See POTASSIUM plus Ammonium Bromide.

MANGANOUS OXIDE MnO

Calcium Hypochlorite	See CALCIUM HYPOCHLORITE plus Iron Oxide.
Fluorine	See FLUORINE plus Trimanganese Tetroxide.

MANGANOUS PERCHLORATE $Mn(ClO_4)_2 6H_2O$

Ethyl Alcohol and 2,2-Dimethoxypropane	See ETHYL ALCOHOL plus Manganese Perchlorate and 2,2-Dimethoxypropane.

MANGANOUS PHOSPHIDE Mn_3P_2

Chlorine	See CHLORINE plus Manganese Ditritaphosphide.

MANGANOUS SULFIDE MnS

Air	Red manganese sulfide, when dried in vacuo, becomes red-hot when exposed to air. *Mellor* **12:** 344 (1946-1947).

MANGANOUS TETRAHYDROALUMINATE $Mn(AlH_4)_2$

Air	Manganese aluminohydride is spontaneously flammable in air. *Chem. Abst.* **49:** 766e (1955). J. Aubrey and G. Monnier, *Comp. Rend.* **238:** 2534-2535 (1954).

MERCAPTANS RSH

Calcium Hypochlorite	See CALCIUM HYPOCHLORITE plus Mercaptans.

MERCURIC AZIDE $Hg(N_3)_2$

(self-reactive)	Mercuric azide decomposes at 190¡ C. It is explosively unstable. *Mellor* **8, Supp. 2:** 43 (1967).

MERCURIC BROMIDE $HgBr_2$

Sodium	See SODIUM plus Ferrous Chloride.
Potassium	See POTASSIUM plus Aluminum Bromide.

MERCURIC CHLORIDE $HgCl_2$

Potassium	See POTASSIUM plus Aluminum Bromide.
Sodium	See SODIUM plus Ferrous Chloride.

MERCURIC CHLORITE $Hg(ClO_2)_2$

(self-reactive)	Mercuric chlorite is an explosive salt.
	Mellor **2, Supp. 1:** 575 (1956).

MERCURIC CYANIDE $Hg(CN)_2$

Fluorine	See FLUORINE plus Mercuric Cyanide.
Magnesium	See MAGNESIUM plus Gold Cyanide.

MERCURIC CYANIDE OXIDE $Hg_2(CN)_2O$

(self-reactive)	Several instances are cited where explosions have occurred in handling or manipulating this substance. Rubbing the material is a frequent cause of the explosions.
	Chem. Abst. **16:** 2010 (1972).
	Chem. Abst. **11:** 300 (1917).

MERCURIC FLUORIDE HgF_2

Potassium	See POTASSIUM plus Aluminum Bromide.
Sodium	See SODIUM plus Ferrous Chloride.

MERCURIC IODIDE HgI_2

Chlorine Trifluoride	See CHLORINE TRIFLUORIDE plus Mercuric Iodide.
Potassium	See POTASSIUM plus Aluminum Bromide.
Sodium	See SODIUM plus Ferrous Chloride.

MERCURIC NITRATE $Hg(NO_3)_2$

Acetylene	Acetylene forms a sensitive acetylide when passed into an aqueous solution of mercuric nitrate.
	Mellor **4:** 933 (1946-1947).
Ethyl Alcohol	Alcohols should not be mixed with mercuric nitrate, as explosive mercury fulminate may be formed.
	Bahme, p. 9 (1961).
Hypophosphoric Acid	Mercuric nitrate is violently reduced to mercury by hypophosphoric acid.
	Mellor **4:** 993 (1946-1947).
Phosphine	The reaction of these materials gives a yellow precipitate which explodes when heated or subjected to shock.
	Mellor **4:** 993 (1946-1947).
Sulfur	See SULFUR plus Mercuric Nitrate.
Unsaturates;	Mercuric nitrate reacts with unsaturates and
Aromatics	aromatics with violence if given time to generate enough heat.
	J. Ball, *Chem. Eng. News* **26:** 3300 (1948).

MERCURIC NITRIDE Hg_3N_2

(self-reactive)	Mercuric nitride is said to be very explosive.
	Mellor **8:** 107 (1946-1947).
Sulfuric Acid	Mercuric nitride explodes when brought in contact with

	sulfuric acid.
	Mellor **8:** 108 (1946-1947).

MERCURIC OXIDE HgO

Chlorine	See CHLORINE plus Mercuric Oxide.
Hydrazine Hydrate	When hydrazine hydrate is dropped on mercuric oxide, an explosion may occur.
	Mellor **8:** 318 (1946-1947).
Hydrogen Peroxide	See LEAD DIOXIDE plus Hydrogen Peroxide.
Hypophosphorous Acid	Hypophosphorous acid reduces mercuric oxide explosively to the metal.
	Mellor **4:** 778 (1946-1947).
Iodine, Methyl Alcohol, and Ethyl Alcohol	See IODINE plus Ethyl Alcohol, Methyl Alcohol, and Mercuric Oxide.
Magnesium	See MAGNESIUM plus Beryllium Oxide.
Phospham	See PHOSPHAM plus Cupric Oxide.
Phosphorus	See PHOSPHORUS plus Mercuric Oxide.
Sodium-Potassium Alloy	See SODIUM-POTASSIUM plus Mercuric Oxide.
Sulfur	See SULFUR plus Mercuric Oxide.

MERCURIC SULFATE $HgSO_4$

Hydrogen Chloride	Absorption of gaseous hydrogen chloride on mercuric sulfate becomes violent at 125¡ C.
	Mellor **2, Supp. 1:** 462 (1956).

MERCURIC SULFIDE HgS

Chlorine	See CHLORINE plus Mercuric Sulfide.
Chlorine Monoxide	See CHLORINE MONOXIDE plus Calcium Phosphide.
Silver Oxide	See SILVER OXIDE plus Antimony Trisulfide.

MERCUROUS AZIDE HgN_3

(self-reactive)	Mercurous azide decomposes at 210¡ C. It is explosively unstable.
	Mellor **8, Supp. 2:** 43 (1967).

MERCUROUS CHLORIDE HgCl

Potassium	See POTASSIUM plus Aluminum Bromide.
Sodium	See SODIUM plus Ferrous Chloride.

MERCUROUS FLUORACETYLIDE FC≡CHg

(self-reactive)	See FLUORACETYLENE (self-reactive)

MERCUROUS HYPOPHOSPHATE $Hg_4P_2O_6$

(self-reactive)	Mercurous hypophosphate decomposes explosively.
	Mellor **8, Supp. 3:** 651 (1971).

MERCUROUS NITRATE $HgNO_3$

Carbon	See CARBON plus Mercurous Nitrate.
Phosphorus	See PHOSPHORUS plus Mercurous Nitrate.

MERCUROUS OXIDE Hg_2O

Hydrogen Peroxide	Mixture reacts with explosive violence.
	V. Autropoff, *J. Prakt. Chem.* **77:** 316 (1908).

Hydrogen Sulfide, Barium Oxide and Air	See HYDROGEN SULFIDE plus Soda Lime.
Potassium	See POTASSIUM plus Mercurous Oxide.
Sodium	See POTASSIUM plus Mercurous Oxide.
Sulfur	See SULFUR plus Mercurous Oxide.

MERCURY Hg

Acetylene	Insoluble, explosive acetylide is formed with mercury.
	Von Schwartz, p. 142 (1918).
Ammonia	Mercury and ammonia can produce explosive compounds. A residue resulting from such a reaction exploded when an attempt was made to clean out the residue with a steel rod.
	C. Van Brunt, *Science* **65:** 63-4 (1927). L.M. Henderson, *Ind. & Eng. Chem. News* **10:** 73 (1932). *Chem. Eng. News* **25:** 2138 (1947).
	See also GOLD plus Ammonia.
Boron Phosphodiiodide	When thrown into mercury vapor, boron phosphodiiodide ignites at once.
	Mellor **8:** 845 (1946-1947).
Chlorine	Flame forms with chlorine jet over mercury surface at 200¡ -300¡ C.
	Mellor **2, Supp. 1:** 381 (1956).
Chlorine Dioxide	Chlorine dioxide and liquid mercury explode violently.
	Mellor **2:** 288 (1946-1947). *Von Schwartz,* p. 142 (1918).
Methyl Azide	Methyl azide in the presence of mercury was shown to be potentially explosive.
	C.L. Currie and B. Darwent, *Can. J. Chem.* **41:** 1048 (1963).
Sodium Carbide	Ground mixtures of sodium carbide and mercury, aluminum, lead, or iron can react vigorously.

	Mellor **5:** 848 (1946-1947).

MERCURY SALTS

Acetylene	Mercury salts and silver salts give acetylides from ammoniacal solutions in the same way copper salts do. The dried acetylides are extremely sensitive and violent.
	G. Benson, *Comp. Gas Bull.* (Oct. 18, 1950); J.K. Luchs, *Phot. Sci. Eng.* 10:334-7 (1966).
Butynediol and Acid	See BUTYNEDIOL plus Hydroxides.
Nitromethane	See COPPER SALTS plus Nitromethane.

MERCURY TETRAPHOSPHIDE Hg_3P_4

Air	Mercury tetratriphosphide ignites when warmed in air, or in chlorine at ordinary temperatures. Mixed with potassium chlorate, it explodes by percussion.
	Comp. Rend. **115:** 230.
Chlorates	See MERCURY TETRATRIPHOSPHIDE plus Air.
Chlorine	See MERCURY TETRATRIPHOSPHIDE plus Air.
Potassium Chlorate	See MERCURY TETRATRIPHOSPHIDE plus Air.

MESITYLENE $C_6H_3(CH_3)_3$

Nitric Acid	See NITRIC ACID plus Mesitylene.

MESITYL OXIDE $(CH_3)_2C{=}CHCOCH_3$

2-Aminoethanol	Mixing mesityloxide and 2-aminoethanol in a closed container caused the temperature and pressure to increase.
	Flynn and Rossow (1970). See Note under complete reference.
Chlorosulfonic Acid	Mixing mesityl oxide and chlorosulfonic acid in a closed container caused the temperature and pressure to increase.

	Flynn and Rossow (1970). See Note under complete reference.
Ethylene Diamine	Mixing mesityl oxide and ethylene diamine in a closed container caused the temperature and pressure to increase.
	Flynn and Rossow (1970). See Note under complete reference.
Nitric Acid	Mixing mesityl oxide and nitric acid in a closed container caused the temperature and pressure to increase.
	Flynn and Rossow (1970). See Note under complete reference.
Oleum	Mixing mesityl oxide and oleum in a closed container caused the temperature and pressure to increase.
	Flynn and Rossow (1970). See Note under complete reference.
Sulfuric Acid	Mixing mesityl oxide and 96% sulfuric acid in a closed container caused the temperature and pressure to increase.
	Flynn and Rossow (1970). See Note under complete reference.

METALLIC HALIDES

Bromine Pentafluoride	See BROMINE PENTAFLUORIDE plus Metal Oxides.

METAL OXIDES

Bromine Pentafluoride	See BROMINE PENTAFLUORIDE plus Metal Oxides.
Performic Acid	Metal oxides catalyze the decomposition of performic acid, resulting in an explosion.
	Grignard **11:** 179 (1935-1954).

METALS

Ammonium Nitrate	See AMMONIUM NITRATE plus Metals (powdered).
Bromine Pentafluoride	Very violent reactions may occur between bromine

	pentafluoride and powdered or warmed metals.
	Mellor **2, Supp. 1:** 172 (1956).
Bromine Trifluoride	Halogen fluorides appear to react with all metals. The reaction is vigorous when no film forms.
	Mellor **2, Supp. 1:** 163 (1956).
Chlorates	See CHLORATES plus Metals (powdered).
Performic Acid	Metals catalyze the decomposition of performic acid and can make it explosive.
	Grignard **11:** 179 (1935-1954).

METAL SULFIDES

Bromates	A combination of finely divided metal sulfides with finely divided bromates (also chlorates and iodates) of barium, calcium, magnesium, potassium, sodium, and zinc can be exploded by heat, percussion and, sometimes, light friction.
	Mellor **2:** 310 (1946-1947).
Chlorates	See METAL SULFIDES plus Bromates. See COPPER SULFIDE plus Cadmium Chlorate.
Chloric Acid	See COPPER SULFIDE plus Cadmium Chlorate. See ANTIMONY SULFIDE plus Chloric Acid.
Hydrazine Mononitrate	See ZINC plus Hydrazine Mononitrate.
Iodates	See METAL SULFIDES plus Bromates.
Silver Oxide	See SILVER OXIDE plus Antimony Trisulfide.

METHANE CH_4

Bromine Pentafluoride	See BROMINE PENTAFLUORIDE plus Acetic Acid.
Chlorine	See CHLORINE plus Methane.
Chlorine Dioxide	See CHLORINE DIOXIDE plus Butadiene.

Nitrogen Trifluoride	See HYDROGEN plus Nitrogen Trifluoride.
Oxygen (Liquid)	See OXYGEN (LIQUID) plus Methane.
Oxygen Difluoride	See HYDROGEN plus Oxygen Difluoride.

METHANOL CH_3OH

Chromic Anhydride	See CHROMIC ANHYDRIDE plus Methyl Alcohol.
Iodine, Ethyl Alcohol and Mercuric Oxide	See IODINE plus Ethyl Alcohol, Methyl Alcohol, and Mercuric Oxide.
Lead Perchlorate	See LEAD PERCHLORATE plus Methyl Alcohol.
Perchloric Acid	See PERCHLORIC ACID plus Ethyl Alcohol.
Phosphorus Trioxide	See DIMETHYL FORMAMIDE plus Phosphorus.
Potassium Hydroxide and Chloroform	See SODIUM HYDROXIDE plus Chloroform and Methyl Alcohol.
Sodium Hydroxide and Chloroform	See SODIUM HYDROXIDE plus Chloroform and Methyl Alcohol.

p-METHOXYBENZYL FORMATE $CH_3OC_6H_4CH_2OCHO$

Phosgene

In the formation of p-methoxybenzyl formate by the addition of phosgene to alcohols followed by the addition of sodium nitride or hydrazoic acid in the presence of pyridine, reaction of phosgene with the azide can cause the formation of explosive carbazide. To prevent the reaction, complete removal of excess phosgene is advocated by passing nitrogen into the solution prior to addition of the azide.

Chem. Abst. **73:** 14099h (1970). *Chem. Phar. Bull.* **18** (4): 850-851 (1970).

2-METHOXYETHANOL $HOCH_2CH_2OCH_3$

Air

Ethylene glycol monomethyl ether forms peroxides that are highly explosive.

Wischmeyer (1969).

2(2-METHOXYETHOXY) ETHANOL $CH_3OCH_2CH_2OCH_2CH_2OH$

Calcium Hypochlorite	See CALCIUM HYPOCHLORITE plus Methyl Carbitol.
Chlorosulfonic Acid	Mixing diethylene glycol monomethyl ether and chlorosulfonic acid in a closed container caused the temperature and pressure to increase. *Flynn and Rossow* (1970). See Note under complete reference.
Oleum	Mixing diethylene glycol monomethyl ether and oleum in a closed container caused the temperature and pressure to increase. *Flynn and Rossow* (1970). See Note under complete reference.

BIS(2-METHOXYETHYL)ETHER $(CH_3OCH_2CH_2)_2O$

Lithium Aluminum Hydride	See LITHIUM ALUMINUM HYDRIDE plus Diethylene Glycol Dimethyl Ether.

METHYL ACETYLENE

(See PROPYNE)

METHYL ALCOHOL

(See METHANOL)

METHYL ALUMINUM SESQUICHLORIDE

(See TRICHLOROTRIMETHYLDIALUMINUM)

METHYL AZIDE CH_3N_3

(self-reactive)	Methyl and ethyl azides are stable at room temperatures but are likely to detonate upon rapid heating.
	J. H. Bover and F. C. Canter, *Chem. Reviews* **54:** 32-3 (1954).
Dimethyl Malonate and Sodium Methylate	A serious explosion occurred in the condensation of methyl azide with dimethyl malonate in the presence of sodium methylate.
	Ch. Grundmann and H. Haldenwanger, *Angew Chem.* **62A:** 410 (1950).
Mercury	See MERCURY plus Methyl Azide.

METHYL 2-AZIDOBENZOATE $CH_3OCOC_6H_4$-2-NNN

(self-reactive)	During distillation of this material the apparatus exploded.
	Wischmeyer (1972).

METHYL BROMIDE CH_3Br

Aluminum	See ALUMINUM plus Methyl Bromide.
Dimethyl Sulfoxide	A reaction between methyl bromide and dimethyl sulfoxide resulted in an explosion that shattered the apparatus.
	Scaros and Serauskas (1973).

METHYL CARBITOL $CH_3OCH_2CH_2OCH_2CH_2OH$

Calcium Hypochlorite	See CALCIUM HYPOCHLORITE plus Methyl Carbitol.

METHYL CHLORIDE CH_3Cl

Aluminum	See ALUMINUM plus Methyl Chloride.
Magnesium	See MAGNESIUM plus Chloroform.

Potassium	See POTASSIUM plus Chloroform.
Sodium	See POTASSIUM plus Chloroform.
	See SODIUM plus Methyl Chloride.
Sodium-Potassium Alloy	See SODIUM-POTASSIUM ALLOY plus Carbon Tetrachloride.

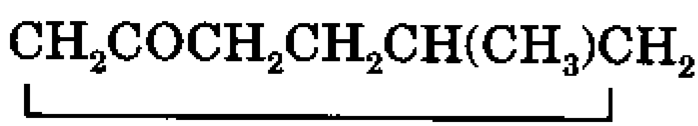
METHYL CHLOROFORM CH_3CCl_3

(See under TRICHLOROETHANE or under other reactant plus trichloroethane)

METHYLCOPPER CH_3Cu

Air	Methyl copper explodes violently when allowed to dry in air.
	Coates, p. 172 (1956).

4-METHYLCYCLOHEXANONE



Nitric Acid	See NITRIC ACID plus 4-Methylcyclohexanone.

n-METHYL n,n-bis DIETHYLBORINIMIDE

(See METHYL-bis (DIETHYLBORYL) AMINE)

METHYL-bis (DIETHYLBORYL) AMINE $((C_2H_5)_2B)_2NCH_3$

Air	n-Methyl n,n-bis diethylborinicimide is spontaneously flammable in air.

	Buls, Bimonthly Rept. 6, p. 3 (1953).

METHYLENE CHLORIDE $ClCH_2Cl$

(See DICHLOROMETHANE)

Lithium	See LITHIUM plus Bromoform.
N-Methyl-N-Nitroso Urea and Potassium Hydroxide	See N-METHYL-N-NITROSO UREA plus Potassium Hydroxide and Methylene Chloride.
Potassium Tert.-Butoxide	See ACETONE plus Potassium Tert.-Butoxide.
Sodium-Potassium Alloy	See SODIUM-POTASSIUM ALLOY plus Methyl Dichloride.

METHYLENE DIISOCYANATE $OCN-CH_2-NCO$

Dimethyl Formamide	See DIMETHYL FORMAMIDE plus Methylene Diisocyanate.

METHYLENE DILITHIUM

(See LITHIUM METHYLIDE)

METHYLENE IODIDE ICH_2I

Lithium	See LITHIUM plus Bromoform.

METHYLENE MAGNESIUM

(See MAGNESIUM METHYLIDE)

METHYL ETHYL ETHER

(See ETHYL METHYL ETHER)

METHYL ETHYLIODOARSINE

(See ETHYLIODOMETHYLARSINE)

METHYL FORMAMIDE CH_3NHCHO

Benzenesulfonyl Chloride	See METHYL ISONITRILE (self-reactive).

METHYLHYDRAZINE CH_3NHNH_2

Air	Exposure of monomethylhydrazine in air on a large surface may result in spontaneous ignition. *Def. Res. and Eng.,* p. 27 (1963).

METHYL HYPOCHLORITE CH_3OCl

(self-reactive)	Methyl hypochlorite decomposes explosively when exposed to light and rapidly even in its absence. *Mellor* **2, Supp. 1:** 550 (1956). See also ALCOHOLS plus Hypochlorus Acid.

METHYL ISONITRILE

(See ISOCTANOMETHANE)

METHYLLITHIUM CH_3Li

Air	Methyl lithium is spontaneously flammable in air. *Douda* (1966). *Mellor* **2, Supp. 2:** 91 (1961).

METHYL METHACRYLATE $CH_2=C(CH_3)COOCH_3$

Benzoyl Peroxide	See BENZOYL PEROXIDE plus Methyl Methacrylate.

METHYL METHACRYLATE POLYMER

Fluorine	See FLUORINE plus Solid Nonmetals and Oxygen.

N-METHYL-N-NITROSO UREA $ON-N(CH_3)CONH_2$

Potassium Hydroxide and Methylene Chloride	Diazomethane was being prepared by portion-wise additions of N-methyl-N-nitroso urea to a flask containing 40% potassium hydroxide and methylene chloride. At the fourth addition a loud detonation occurred.
	MCA Guide for Safety, p. 301 (1972).

METHYL PARATHION $(CH_3O)_2P(S)OC_6H_4NO_2$

(self-reactive)	When a sample was heated in a small test tube it decomposed and in a few minutes the residue exploded.
	J. B. McPherson and G. A. Johnson, *Agri. Food Chem.* **4** (1): 42 (1956).

METHYLOLACRYLAMIDE

(See n-HYDROXYMETHYLACRYLAMIDE)

2-METHYL-3-PHENYL-1-PROPANOL
$C_6H_5CH_2CH(CH_3)CH_2OH$

Hydrogen Peroxide and Sulfuric Acid	See ALCOHOLS plus Hydrogen Peroxide and Sulfuric Acid.

METHYL PERCHLORATE CH_3ClO_4

(self-reactive)	Methyl, ethyl, and propyl perchlorates are oily liquids of extraordinary explosive power, extremely sensitive to heat, shock, and friction.
	ACS **146:** 214. *Berichte* **42:** 4390-4 (1909).
	Z. Anorg. Chemie **228:** 341-51 (1936).

METHYLPHOSPHINE CH_3PH_2

Air	Methyl phosphine is spontaneously flammable in air.
	Hurd, p. 128 (1952).

METHYLSILYLAMINO DIBORANE $(B_2H_5)N(CH_3)(SiH_3)$

Air	Methyl silyamino diborane is spontaneously flammable in air.
	Douda (1966).

METHYLSODIUM CH_3Na

Air	Methyl sodium is spontaneously flammable in air.
	Douda (1966).

METHYL TRICHLOROSILANE

(See TRICHLOROMETHYLSILANE)

METHYL(TRIFLUOROPROPYL)POLYSILOXANE

Fluorine	See FLUORINE plus Solid Nonmetals and Oxygen.

MOLYBDENUM Mo

Bromine Trifluoride	Powdered molybdenum, powdered titanium, and powdered vanadium all react with bromine trifluoride, producing incandescence.

	Mellor **2, Supp. 1:** 164 (1956).
	Reaction between molybdenum or tungsten and bromine trifluoride is vigorous. No protective film forms with the volatile hexafluoride of the metal.
	Mellor **2, Supp. 1:** 163 (1956).
Chlorine Trifluoride	Chlorine trifluoride acts on powdered molybdenum with incandescence.
	Z. Anorg. Chemie **190:** 270.
	Mellor **2, Supp. 1:** 156 (1956).
Fluorine	Fluorine acts on powdered molybdenum with incandescence. Other interhalogen compounds containing fluorine may act similarly.
	Z. Anorg. Chemie **190:** 270.
Lead Dioxide	Powdered molybdenum or tungsten mixed with lead dioxide becomes incandescent when heated.
	Mellor **7:** 691 (1946-1947).

MOLYBDENUM DISULFIDE MoS_2

Hydrogen Peroxide	See ANTIMONY TRISULFIDE plus Hydrogen Peroxide.

MOLYBDENUM TRIOXIDE MoO_3

Chlorine Trifluoride	Chlorine trifluoride attacks molybdenum trioxide with incandescence.
	Z. Anorg. Chemie **190:** 270.
	See also CHLORINE TRIFLUORIDE plus Aluminum Oxide.
Lithium	See LITHIUM plus Molybdenum Trioxide.
Magnesium	See MAGNESIUM plus Molybdenum Trioxide.
Potassium	See POTASSIUM plus Molybdenum Trioxide.
Sodium	See POTASSIUM plus Molybdenum Trioxide.

MONEL

Fluorine	See FLUORINE plus Metals.

MONOAMMONIUM PHOSPHATE $NH_4H_2PO_4$

Sodium	See SODIUM plus Monoammonium Phosphate.
Sodium Bicarbonate	See SODIUM BICARBONATE plus Monoammonium Phosphate.

MONOFLUOROTRICHLOROMETHANE

(See TRICHLOROFLUOROMETHANE)

NaK

(See SODIUM-POTASSIUM ALLOY)

NAPHTHALENE $C_{10}H_8$

Chromic Anhydride	See CHROMIC ANHYDRIDE plus Naphthalene.

NEODYMIUM Nd

Air	See RARE EARTH METALS plus Air.
Halogens	See RARE EARTH METALS plus Halogens.
Nitrogen	Neodymium and nitrogen react vigorously.
	Mellor **8, Supp. 1:** 164 (1964).
Phosphorus	Neodymium and phosphorus react vigorously at 400¡ — 500¡ C.
	Mellor **8, Supp. 3:** 347 (1971).

NEODYMIUM PHOSPHIDE NdP

Nitric Acid	Neodymium phosphide and nitric acid react violently.
	Mellor **8, Supp. 3:** 348 (1971).
Water	See CEROUS PHOSPHIDE plus Water.

NEOPRENE $(CH_2{=}CClCH{=}CH_2)_x$

Fluorine	See FLUORINE plus Solid Nonmetals and Oxygen.
Fluorine (liquid)	See FLUORINE plus Neoprene.

NICKEL Ni

Ammonium Nitrate	See AMMONIUM NITRATE plus Metals (powdered).
Fluorine	See FLUORINE plus Metals.
Hydrazine	The catalytic decomposition of hydrazine in the presence of Raney nickel may be vigorous at room temperature.
	Mellor **8, Supp. 2:** 83 (1967).
Hydrazoic Acid	Raney nickel and hydrazoic acid undergo a vigorous decomposition.
	Mellor **8, Supp. 2:** 4 (1967).
Hydrogen and Dioxane	See HYDROGEN plus Dioxane and Nickel (Raney).
Performic Acid	Powdered nickel can decompose performic acid violently.
	Berichte **48:** 1139 (1915).
Phosphorus	See COPPER plus Phosphorus.
Selenium	When powdered nickel is heated with selenium or sulfur, the elements unite with incandescence.
	Berichte **14:** 2823. *Comp. Rend.* **131:** 557. G. Little, *Ann. Chem.* **112:** 211 (1859).
Sulfur	See SULFUR plus Nickel.
Titanium and Potassium Perchlorate	Mixtures containing potassium perchlorate with nickel and titanium powders and infusorial earth gave

severe explosions during a friction test. Very small sparks — less than those available from static electricity on the human body — can ignite the mixture.

ACS **146:** 210. *BM Info. Circ.* **7349** (1945).

NICKEL ALLOYS

Lithium	See LITHIUM plus Cobalt Alloys.

NICKEL BROMIDE $NiBr_2$

Potassium	See POTASSIUM plus Aluminum Bromide.

NICKEL CARBONYL $Ni(CO)_4$

Air	In the presence of air, nickel carbonyl forms a deposit which becomes peroxidized. This tends to decompose and ignite. See also NICKEL CARBONYL plus n-Butane and Oxygen. Edgerton & Radra-Kanchana, *Proc. Roy. Soc.* **A225:** 427 (1954).
Bromine	See BROMINE plus Nickel Carbonyl.
n-Butane and Oxygen	Nickel carbonyl vapor explodes in air or oxygen at 20¡C. and a partial pressure of 15 mm. Addition of nickel carbonyl to an n-butane-oxygen mixture causes explosion at 20-40¡C. E. J. Badin, P. C. Hunter, R. N. Pease, *J. Am. Chem. Soc.* **70:** 2055-6 (1948).
Oxygen	See NICKEL CARBONYL plus n-Butane and Oxygen.

NICKEL CHLORIDE $NiCl_2$

Potassium	See POTASSIUM plus Aluminum Bromide.

NICKEL CHLORITE $Ni(ClO_2)_2$

(self-reactive)	The dihydrate of nickel chlorite explodes when heated to

100¡C.

Mellor **2, Supp. 1:** 574 (1956).

NICKEL CYANIDE $Ni(CN)_2$

Magnesium	See MAGNESIUM plus Cadmium Cyanide.

NICKEL FLUORIDE NiF_2

Potassium	See POTASSIUM plus Ammonium Bromide.

NICKEL-HEXAMMINE CHLORATE $Ni(NH_3)_6(ClO_3)_2$

(self-reactive)	This compound detonates when struck. *Mellor* **2, Supp. 1:** 592 (1956)

NICKEL-HEXAMMINE PERCHLORATE $Ni(NH_3)_6(ClO_4)_2$

(self-reactive)	This compound detonates when struck but is less sensitive than hexamminonickel chlorate. *Mellor* **2, Supp. 1:** 592 (1956).

NICKEL HYPOPHOSPHITE $Ni(PH_2O_2)_2$

(self-reactive)	Nickel hypophosphite liberates spontaneously flammable phosphine above 100¡C. *Mellor* **8:** 890 (1946-1947).

NICKEL IODIDE NiI_2

Potassium	See POTASSIUM plus Aluminum Bromide.

NICKEL MONOXIDE NiO

Fluorine	See FLUORINE plus Nickel Monoxide.
Hydrogen Sulfide, Barium Oxide and Air	See HYDROGEN SULFIDE plus Soda Lime.

NICKEL NITRIDE Ni_3N

Acids	The reaction of nickel nitride and acids may be explosive with high acid concentrations and heat. *Mellor* **8, Supp. 1:** 238 (1964).

NICKEL PERCHLORATE $Ni(ClO_4)_2$

2,2-Dimethoxypropane	When nickel perchlorate and 2,2-dimethoxypropane were heated, a violent reaction occurred. *Chem. Eng. News* **48** (28): 7-8 (Oct. 26, 1970). See also 2,2-DIMETHOXYPROPANE plus Manganese Perchlorate and Ethyl Alcohol.
Hydrazine	The blue precipitate formed from nickel perchlorate and hydrazine in water exploded violently when a glass stirring rod was introduced into the suspension. *ACS* **146:** 209. *Helv. Chim. Acta.* **34:** 2084-5 (1951).

NICKEL-TRIHYDRAZINE CHLORATE $Ni(N_2H_4)_3(ClO_3)_2$

(self-reactive)	This compound detonates when struck. *Mellor* **2, Supp. 1:** 592 (1956).

NICKEL-TRIHYDRAZINE NITRATE $Ni(NO_3)3H_2NNH_2$

(self-reactive)	A small amount of thoroughly washed, dry trihydrazine nickel nitrate exploded about ten minutes after exposure to the atmosphere.

H. Ellern and D. E. Olander, *J. Chem. Edu.* **32:**24 (1955).

NIOBIUM (COLUMBIUM) Nb

Bromine Trifluoride	Niobium and tantalum each reacts with bromine trifluoride with incandescence.
	Mellor **2, Supp. 1:** 164 (1956).
Chlorine	Powdered niobium reacts energetically with chlorine.
	Mellor **2, Supp. 1:** 381 (1956).
	See NIOBIUM plus Fluorine.
Fluorine	At ordinary temperatures, niobium (columbium) becomes incandescent in the presence of fluorine. It ignites when gently heated in chlorine.
	Mellor **9:** 849 (1946-1947).

NIOBIUM PENTOXIDE Nb_2O_5

Aluminum and Sulfur	See ALUMINUM plus Niobium Oxide and Sulfur.
Bromine Trifluoride	See BROMINE TRIFLUORIDE plus Bismuth Pentoxide.
Lithium	See LITHIUM plus Niobium Pentoxide.

NITRATE-NITRITE

Aluminum	See ALUMINUM plus Nitrate-Nitrite and Organic Matter.
Organic Matter	See ALUMINUM plus Nitrate-Nitrite and Organic Matter.

NITRATES

(See also specific nitrates as primary entries or under other reactants)

Aluminum	See ALUMINUM plus Nitrates.
Boron Phosphide	See BORON PHOSPHIDE plus Nitric Acid.
Cyanides	Addition of cyanides to a molten nitrate bath (or vice versa)

	will result in an explosion.
	NBFU Research Report **2** (1950).
Esters	A mixture of the two may cause an explosion.
	Pieters, p. 30 (1957).
Phospham	A mixture of phospham and a nitrate explodes when heated.
	H. Rose, *Ann. Phys.* **24:** 308 (1832).
Phosphorus	See PHOSPHORUS plus Nitrates.
Sodium Cyanide	See NITRATES plus Cyanides.
Sodium Hypophosphite	See CHLORATES plus Sodium Hypophosphite.
Stannous Chloride	A mixture of the two may cause an explosion.
	Pieters, p. 30 (1957).
Thiocyanates	See THIOCYANATES plus Chlorates.

NITRIC ACID HNO_3

Acetic Acid	Acetic acid or acetic anhydride can explode with nitric acid if not kept cold.
	Von Schwartz, p. 321 (1918). *Comp Rend.* **269** (15): 1114-1116 (1968).
Acetic Anhydride	See NITRIC ACID plus Acetic Acid.
	See ACETIC ANHYDRIDE plus Nitric Acid.
	Experiments demonstrate that mixtures containing more than 50% by weight of nitric acid in acetic anhydride may act as detonating explosives under certain conditions. An indication is given of the percentage mixtures of acetic anhydride-nitric acid which could be detonated using a priming charge and detonator.
	BCISC **42** (166): 2 (1971).
Acetone and Acetic	An etching reagent of equal parts of acetone,
Acid	concentrated nitric acid, and 75 per cent acetic acid exploded four hours after it was prepared and placed in a

	closed bottle. A correspondent pointed out that this formulation is similar to the method of preparing tetranitromethane, a sensitive explosive.
	Chem. Eng. News **38** (43): 56 (1960); **38** (46): 5 (1960).
Acetone and Sulfuric Acid	Acetone will decompose violently when brought in contact with mixed sulfuric-nitric acids, especially if the reaction is in a confined or a narrow-mouthed container.
	Ind. Eng. Chem. **51:** 59A (April 1959).
Acetylene	Concentrated nitric acid on acetylene gives trinitromethane, which melts at 15¡ C and is explosive in the liquid state.
	Kirk and Othmer **9:** 430-2 (1947).
Acrolein	See ACROLEIN plus Nitric Acid.
Acrylonitrile	See ACRYLONITRILE plus Nitric Acid.
Allyl Alcohol	See ALLYL ALCOHOL plus Nitric Acid.
Allyl Chloride	See ALLYL CHLORIDE plus Nitric Acid.
2-Aminoethanol	See 2-AMINOETHANOL plus Nitric Acid.
Ammonia	Ammonia gas burns in an atmosphere of nitric acid vapor.
	Mellor **8:** 219 (1946-1947).
	See NITRIC ACID plus Diborane.
Ammonium Hydroxide	Mixing 70% nitric acid and 28% ammonium hydroxide in a closed container caused the temperature and pressure to increase.
	Flynn and Rossow (1970). See Note under complete reference.
	Mellor **8, Supp. 1:** 349 (1964).
Aniline	Aniline ignites spontaneously in the presence of red fuming nitric acid.
	Kit and Evered, pp. 238-42 (1960).
	A self-flammable fuel is prepared by adding a hydrocarbon to a mixture of concentrated nitric acid and an oxidation catalyst. The hydrocarbon contains a combustion initiator made up of aniline, dimethyl aniline, xylidene, and iron

pentacarbonyl.

Aniline, p. 85 (1964).

Aromatic amines (e.g., aniline or toluidine) in triethylamine solution are ignited rapidly by red fuming nitric acid at temperatures of minus 76¡ or lower.

Aero. Tech. Note **3884** (1956).

Brennstoff-Chem. **46** (4): 117-24 (1965). *Chem. Abst.* **51:** 3961d (1957); **63:** 4067h (1965).

See also NITRIC ACID plus Diborane.

Anion Exchange Resins	If hydroxyl-form anion exchange resins are contacted by nitric acid solutions of excessive strength (e.g. 6 molar), rapid heating and resulting gaseous degradation products can pressurize and damage the ion-exchange vessel.
	Van Slyke (1967). *Reactor Fuel Process.* **7** (4): 297-303 (Fall 1964). *AEC Research and Devel. Report, B N WL*-476 (January 1967).
Anion Exchange Resins and Dichromate	Dichromate loadings as low as 0.05 grams per cubic centimeter of resin in contact with 7 molar nitric acid can cause a runaway reaction.
	Ignition temperature is 92¡ C and decreases with increasing dichromate loading.
	AEC Research and Devel. Report BNWL-**144** (August 1965).
Antimony	See ANTIMONY plus Nitric Acid.
Arsine	Fuming nitric acid reacts explosively with arsine.
	Mellor **9:** 56 (1946-1947).
Bismuth	See BISMUTH plus Nitric Acid.
Boron	See BORON plus Nitric Acid.
Boron Decahydride	See BORON DECAHYDRIDE plus Nitric Acid.
Boron Phosphide	See BORON PHOSPHIDE plus Nitric Acid.

Bromine Pentafluoride	See BROMINE PENTAFLUORIDE plus Nitric Acid.
n-Butyraldehyde	See n-BUTYRALDEHYDE plus Nitric Acid.
Calcium Hypophosphite	See CALCIUM HYPOPHOSPHITE plus Nitric Acid.
Carbon	See CARBON plus Nitric Acid.
Cesium Carbide	See CESIUM CARBIDE plus Nitric Acid.
4-Chloro-2-Nitroaniline	See 4-CHLORO-2-NITROANILINE plus Nitric Acid.
Chlorine Trifluoride	See CHLORINE TRIFLUORIDE plus Nitric Acid.
Chlorosulfonic Acid	See CHLOROSULFONIC ACID plus Nitric Acid.
Cresol	See CRESOL plus Nitric Acid.
Cumene	See CUMENE plus Nitric Acid.
Cupric Nitride	See CUPRIC NITRIDE plus Nitric Acid.
Cuprous Nitride	See CUPROUS NITRIDE plus Sulfuric Acid.
Cyanides	This mixture produces an explosive reaction.
	Scott (1967).
Cyclic Ketones	The cyclic ketones are far more susceptible to violent reaction than are the corresponding cyclic alcohols.
	Chem. Eng. News **37** (35): 48 (Aug. 31, 1959).
Cyclohexanol	Cyclohexanol and nitric acid can react at room temperature to form a violently explosive material.
	Chem. & Ind. **1971:** (19) (1971).
Cyclohexanone	Acid burns resulted from the violent reaction of nitric acid with cyclohexanone.
	Dept. of Commerce PB Report **73591.**
Diborane	Mixtures of fuming nitric acid and any of the following are self-igniting: diborane, aniline, terpenes, furfuryl alcohol, and ammonia.
	Mellor **8, Supp. 2:** 341 (1967).
2,6-Di-t-Butylphenol	These ingredients, reacted in a medium of acetic acid, form 2,6-di-t-butyl-4-nitrophenol. Two grams of this nitro

	compound exploded violently after warming on a steam bath for 2-3 minutes. (Possibly a polynitro derivative was the explosive.)
	ASESB Expl. Report **24** (1961).
Diisopropyl Ether	See DIISOPROPYL ETHER plus Nitric Acid.
Epichlorohydrin	See EPICHLOROHYDRIN plus Nitric Acid.
Ethyl Alcohol	Stirring a mixture of concentrated nitric acid and ethyl alcohol results in a reaction that starts slowly and accelerates to an explosion.
	Becker (1965).
	A solution of 190-proof ethyl alcohol plus nitric acid (15 per cent), being used to etch bismuth, decomposed vigorously and sprayed the surrounding area.
	Chem. Eng. News **27:** 1396 (1949).
	See SILVER plus Ethyl Alcohol and Nitric Acid.
m-Ethylaniline	m-Ethylaniline ignites spontaneously in the presence of red fuming nitric acid.
	Kit and Evered, pp. 238-42 (1960).
Ethylene Diamine	See ETHYLENE DIAMINE plus Nitric Acid.
Ethyleneimine	See ETHYLENEIMINE plus Nitric Acid.
5-Ethyl-2-Methyl	These materials were placed in a small auto-clave
Pyridine	and heated and stirred for 40 minutes. The emergency vent was opened due to a sudden pressure rise. A violent explosion occurred 90 seconds later.
	R.L. Frank, *Chem. Eng. News* **30:** 3348 (1952).
5-Ethyl-2-Picoline	See 5-ETHYL-2-PICOLINE plus Nitric Acid.
Ethyl Phosphine	See BROMINE plus Ethyl Phosphine.
Ferrous Oxide	See FERROUS OXIDE plus Nitric Acid.
Fluorine	See FLUORINE plus Nitric Acid.
Furfuryl Alcohol	Furfuryl alcohol is ignited immediately by concentrated nitric acid.

	MCA Case History **193** (1952).
	See also NITRIC ACID plus Diborane.
Germanium	See GERMANIUM plus Nitric Acid.
Glyoxal	Mixing 70% nitric acid and glyoxal in a closed container caused the temperature and pressure to increase.
	Flynn and Rossow (1970). See Note under complete reference.
Hydrazine	See HYDRAZINE plus Air.
	See HYDRAZINE plus Nitric Acid.
Hydrazoic Acid	See HYDRAZOIC ACID plus Nitric Acid.
Hydrogen Iodide	See HYDROGEN IODIDE plus Nitric Acid.
Hydrogen Peroxide	See HYDROGEN PEROXIDE plus Nitric Acid.
Hydrogen Selenide	See HYDROGEN SELENIDE plus Nitric Acid.
Hydrogen Sulfide	See HYDROGEN SULFIDE plus Nitric Acid.
Hydrogen Telluride	Cold fuming nitric acid ignites hydrogen telluride, sometimes explosively.
	Pascal **10:** 505 (1931-1934).
Indane and Sulfuric Acid	See INDANE plus Nitric Acid and Sulfuric Acid.
Isoprene	See ISOPRENE plus Nitric Acid.
Ketones and Hydrogen Peroxide	See KETONES plus Nitric Acid and Hydrogen Peroxide.
Lactic Acid and Hydrofluoric Acid	A mixture of 5 parts lactic acid, 5 parts nitric acid, 2 parts water, and 1 part hydrofluoric acid being stored in a plastic bottle ruptured with explosive force.
	Scott (1967). *NSC Newsletter Aero. Sec.* (May 1967).
Lithium	See LITHIUM plus Nitric Acid.
Lithium Silicide	See LITHIUM SILICIDE plus Nitric Acid.
Magnesium	See MAGNESIUM plus Nitric Acid.

Magnesium Phosphide	See MAGNESIUM PHOSPHIDE plus Nitric Acid.
Magnesium-Titanium Alloy	See TITANIUM-MAGNESIUM ALLOY plus Nitric Acid.
Manganese	See MANGANESE plus Nitric Acid.
Mesitylene	During oxidation of mesitylene with nitric acid in an autoclave at 115¡ C to give 3,5-dimethyl benzoic acid a violent explosion occurred. The reaction was attributed to local overheating, formation of a trinitro compound 1,3,5-tri(nitromethyl) benzene, and to violent decomposition of the latter. Smaller scale preparations with better temperature control were uneventful. Wilma et al, *Angew. Chem. Intern, Ed. Engl.* **74:** 465 (1962).
Mesityl Oxide	See MESITYL OXIDE plus Nitric Acid.
2-Methyl-5-Ethylpyridine	*Chem. Eng. News* **51** (34) 142 (1973).
4-Methylcyclohexanone	The oxidation by nitric acid of 4-methylcyclohexanone to form a dicarboxylic acid resulted in a violent explosion. The methylcyclohexanone was added gradually to the mixture held at 69 to 77¡ C. After an hour of this procedure, the mixture exploded. *Chem. Eng. News* **37** (35): 48 (1959).
Neodymium Phosphide	See NEODYMIUM PHOSPHIDE plus Nitric Acid.
Nitrobenzene	Mixtures of nitric acid and nitrobenzene are detonable, depending on the amount of water present. *Chem. Eng. News* **41** (37):89 (1963).
Oleum	See OLEUM plus Nitric Acid.
Organic Matter	Nitric acid ignites spontaneously with some organic compounds, such as furfuryl alcohol and butyl mercaptan. S.V. Gunn, *J. Am. Rocket Soc.* **22:** 33 (1952). Barrere & Moutet, *Symposium Comb.* **(Fifth):** 170-81 (1954).
Phosphine	See PHOSPHINE plus Nitric Acid.

Phosphonium Iodide	See PHOSPHONIUM IODIDE plus Nitric Acid.
Phosphorus	See PHOSPHORUS plus Nitric Acid.
Phosphorus Tetratriiodide	See PHOSPHORUS TETRATRIIODIDE plus Nitric Acid.
Phosphorus Trichloride	See PHOSPHORUS TRICHLORIDE plus Nitric Acid.
Phthalic Acid	See PHTHALIC ANHYDRIDE plus Nitric Acid.
Phthalic Anhydride	See PHTHALIC ANHYDRIDE plus Nitric Acid.
Potassium Hypophosphite	See POTASSIUM HYPOPHOSPHITE plus Nitric Acid.
Propiolactone (beta-)	See PROPIOLACTONE (beta-) plus Nitric Acid.
Propylene Oxide	See PROPYLENE OXIDE plus Nitric Acid.
Pyridine	See PYRIDINE plus Nitric Acid.
Rubidium Carbide	See RUBIDIUM CARBIDE plus Nitric Acid.
Selenium	See SELENIUM plus Nitric Acid.
Selenium Iodophosphide	See SELENIUM IODOPHOSPHIDE plus Nitric Acid.
Silver and Ethyl Alcohol	See SILVER plus Ethyl Alcohol and Nitric Acid.
Sodium	See SODIUM plus Nitric Acid.
Sodium Azide	See SODIUM AZIDE plus Nitric Acid.
Sodium Hydroxide	See SODIUM HYDROXIDE plus Nitric Acid.
Stibine	See STIBINE plus Nitric Acid.
Sulfamic Acid	See SULFAMIC ACID plus Nitric Acid.
Sulfuric Acid and Glycerides	Sulfuric acid, nitric acid and fat were placed in a tightly closed container. Within 10 minutes, the container exploded.

	Chem. Eng. News **51** (31): 32 (1973).
Terpenes	See NITRIC ACID plus Diborane.
Tetraboron Decahydride	See TETRABORON DECAHYDRIDE plus Nitric Acid.
Thiocyanates	See THIOCYANATES plus Nitric Acid.
Thiophene	See THIOPHENE plus Nitric Acid.
Titanium	See TITANIUM plus Nitric Acid.
Titanium Alloy	See TITANIUM ALLOY plus Nitric Acid.
Titanium-Magnesium Alloy	See TITANIUM-MAGNESIUM ALLOY plus Nitric Acid.
Toluene and Sulfuric Acid	If conditions are not properly controlled, the reaction of toluene with nitric acid is extremely violent especially in the presence of sulfuric acid, which takes up the water formed. Part of the hazard is from the formation of nitrocresols, which react and decompose violently on further nitration.
	Urbanski **1:** 139, 931 (1964).
Toluidine	See NITRIC ACID plus Aniline.
Triazine	Nitrolysis of triazine with 99% nitric acid in a trifluoroacetic anhydride solvent caused a violent explosion at 36¡ C.
	Rolston (1972).
Unsymmetrical Dimethyl Hydrazine	See UNSYMMETRICAL DIMETHYL HYDRAZINE plus Hydrogen Peroxide.
	Also see UNSYMMETRICAL DIMETHYL-HYDRAZINE plus Nitric Acid, Nitrogen Tetroxide, and Sulfuric Acid.
Uranium	See URANIUM plus Nitric Acid.
Uranium-Neodymium Alloy	See URANIUM-NEODYMIUM ALLOY plus Nitric Acid.
Uranium-Neodymium-	See URANIUM-NEODYMIUM-ZIRCONIUM

Zirconium Alloy	ALLOY plus Nitric Acid.
Vinyl Acetate	See VINYL ACETATE plus Nitric Acid.
Vinylidene Chloride	See VINYLIDENE CHLORIDE plus Nitric Acid.
Zinc	See ZINC plus Nitric Acid.
Zirconium-Uranium Alloys	See ZIRCONIUM-URANIUM ALLOYS plus Nitric Acid.

NITRIC OXIDE NO

Aluminum	See ALUMINUM plus Carbon Disulfide.
Boron	See BORON plus Nitrous Oxide.
Carbon Disulfide	A mixture of nitric oxide with the vapor of carbon disulfide gives a green luminous flame.
	Mellor **8:** 436 (1946-1947).
	These compounds react explosively with emission of light.
	Mellor **8, Supp. 2:** 232 (1967).
Chlorine Monoxide	See CHLORINE MONOXIDE plus Nitric Oxide.
Chromium	See CHROMIUM plus Nitric Oxide.
Fluorine	See FLUORINE plus Nitric Oxide.
Fuels	Nitric oxide will burn with nearly all fuels which will burn with air.
	Symposium Comb. **(Fourth):** 420 (1952).
Hydrocarbons	See NITRIC OXIDE plus Fuels.
Nitrogen Trichloride	See NITROGEN TRICHLORIDE plus Ammonia.
Ozone	See OZONE plus Nitric Oxide.
Phosphine	See PHOSPHINE plus Nitric Oxide.
Phosphorus	See PHOSPHORUS plus Nitric Oxide.
Rubidium Carbide	See RUBIDIUM CARBIDE plus Sulfur Dioxide.
Sodium Monoxide	See SODIUM MONOXIDE plus Nitric Oxide.

Unsymmetrical Dimethylhydrazine	This mixture ignites on sparking. *Mellor* **8, Supp. 2:** 234 (1967).
Uranium	See URANIUM plus Nitric Oxide.

NITRIDES

(See specific nitrides as primary entries or see under other reactants)

NITRILES

Lithium Aluminum Hydride and Water	See LITHIUM ALUMINUM HYDRIDE plus Nitriles and Water.

NITRITES

(See also specific nitrites as primary entries or see under other reactants)

Ammonium Salts	A violent explosion occurs if an ammonium salt is melted with a nitrite salt. *Von Schwartz,* p. 299 (1918).
Cyanides	See CYANIDES plus Chlorates.
Potassium Cyanide	A mixture of the two may cause an explosion. *Pieters,* p. 30 (1957). A molten salt bath containing nitrite salts was carefully cleaned before reuse with cyanide-containing salts. However, when the furnace was reheated, a violent reaction and eruption took place. Presumably a residue of nitrite had remained. *Scott* (1966).

o-NITROANILINE DIAZONIUM SALT $O_2NC_6H_3(NO_2)NNX$

Sodium Bisulfide	See SODIUM SULFIDE plus Diazonium Salts and

	Diazonium Chloride Salts.
Sodium Polysulfide	See SODIUM SULFIDE plus Diazonium Salts and Diazonium Chloride Salts.
Sodium Sulfide	See SODIUM SULFIDE plus Diazonium Salts and Diazonium Chloride Salts.

NITROANISOLE $O_2NC_6H_4OCH_3$

(self-reactive)	The explosion of 400 grams of o-nitroanisole during reduction using nickel as a catalyst has been reported.
	J. Am. Chem. Soc. **53:** 2808 (1931).
Hydrogen	See HYDROGEN plus Nitroanisole.

NITROAROMATIC COMPOUNDS

Chlorine Trifluoride	Solutions of nitroaromatic compounds in chlorine trifluoride are extremely sensitive to shock.
	Mellor **2, Supp. 1:** 156 (1956).

NITROBENZENE $C_6H_5NO_2$

Aluminum Chloride	See ALUMINUM CHLORIDE plus Nitrobenzene
and Phenol	and Phenol.
Aniline and Glycerine	See ANILINE plus Nitrobenzene and Glycerine.
Nitric Acid	See NITRIC ACID plus Nitrobenzene.
Nitrogen Tetroxide	See NITROGEN TETROXIDE plus Nitrobenzene.
Silver Perchlorate	See SILVER PERCHLORATE plus Acetic Acid.

NITROBENZENESULFONIC ACID $O_2NC_6H_4SO_3H$

(self-reactive)	Nitrobenzene sulfonic acid is known to decompose violently at about 200¡ C.
	MCA Case History **1482** (1968).

o-NITROBENZOYLACETIC ACID $O_2NC_6H_4COCH_2COOH$

Thionyl Chloride	See THIONYL CHLORIDE plus o-Nitrobenzoylacetic Acid.

o-NITROBENZOYL CHLORIDE $O_2NC_6H_4COCl$

(self-reactive)	See o-NITROPHENYLACETYL CHLORIDE.

N-NITRO-N'2,4-DINITROPHENYLUREA

$(NO_2)_2C_6H_3NHCONHNO_2$

(self-reactive)	This compound is an explosive of less power than picric acid, but of greater sensitivity to friction and impact. *Chem. Eng. News* **18:** 72 (1940).

NITROETHANE $C_2H_5NO_2$

Calcium Hydroxide	See CALCIUM HYDROXIDE plus Nitroethane.
Hydrocarbons	Nitroethane and other nitro compounds are mild oxidizers and should not be heated with easily oxidized hydrocarbons under confinement. *Chem. Eng. News* **30:** 2344 (1952).
Hydroxides	See CALCIUM HYDROXIDE plus Nitroethane.
Inorganic Bases	See CALCIUM HYDROXIDE plus Nitroethane.
Potassium Hydroxide	See CALCIUM HYDROXIDE plus Nitroethane.
Sodium Hydroxide	See CALCIUM HYDROXIDE plus Nitroethane.

NITROFORM $CH(NO_2)_3$

Isopropyl Alcohol	Solutions of 90% nitroform in 10% isopropyl alcohol in polyethylene bottles exploded. Nitroform, especially when the concentration is 50% or greater, dissolves with evolution of heat. This heat is sufficient to initiate the

	reaction.
	ASESB Expl. Report **175.** *MCA Case History* **1010** (1964).

NITROGEN N_2

Lithium	See LITHIUM plus Oxygen.
	See LITHIUM plus Nitrogen.
Neodymium	See NEODYMIUM plus Nitrogen.
Titanium	See TITANIUM plus Nitrogen.

NITROGEN DIOXIDE NO_2; N_2O_4

(See NITROGEN PEROXIDE)

Cyclohexane	See CYCLOHEXANE plus Nitrogen Dioxide.
Fluorine	See FLUORINE plus Nitrogen Dioxide.
Formaldehyde	See FORMALDEHYDE plus Nitrogen Dioxide.

NITROGEN IODIDE NI_3

Ozone	See OZONE plus Nitrogen Iodide.

NITROGEN IODIDES

(self-reactive)	See IODINE plus Ammonium Hydroxide.

NITROGEN PENTOXIDE N_2O_5

Sodium Carbide	See SODIUM CARBIDE plus Nitrogen Pentoxide.

NITROGEN PEROXIDE NO_2; N_2O_4

(See also NITROGEN TETROXIDE)

Acetic Anhydride	This reaction in the attempt to synthesize tetranitromethane

	resulted in a violent explosion.
	Van Dolah (1967).
Aluminum	See ALUMINUM plus Carbon Disulfide.
Ammonia	Solid nitrogen tetroxide reacts explosively with liquid ammonia. With gaseous ammonia, slow reactions start even when cold.
	Comp. Rend. **116:** 756. Parker & Wolfhard, *Symposium Comb.* **(Fourth):** 420 (1952).
	See NITRIC OXIDE plus Ammonia.
Barium Oxide	When nitrogen dioxide is passed over barium oxide (at 200¡ C.) the oxide becomes red-hot and fumes.
	Ann. Chim. et Phys. (2) **2:** 317.
Boron Trichloride	See BORON TRICHLORIDE plus Nitrogen Peroxide.
Carbon Disulfide	Explosives can be prepared from nitrogen dioxide plus carbon disulfide. They can be heated to 200¡ C. without explosion, but can be detonated with mercury fulminate.
	E. Turpin, *German Pat.* 19,676 (1881).
Cesium Acetylene	See CESIUM ACETYLENE CARBIDE plus
Carbide	Nitrogen Dioxide.
Chloroform	See NITROGEN TETROXIDE plus 1,2-Dichloroethane.
1,2-Dichloroethane	Nitrogen tetroxide forms explosive mixtures with incompletely halogenated hydrocarbons.
	Turley (1964). *Chem. Eng. News* **42** (47): 53 (1964).
Dichloroethylene	See NITROGEN TETROXIDE plus 1,2-Dichloroethane.
Ethylene	See NITROGEN TETROXIDE plus Olefins.
Fuels	Nitrogen dioxide burns readily with all fuels which burn in air.
	Parker & Wolfhard, *Symposium Comb.* (**Fourth**): 420 (1952).
	See NITROGEN TETROXIDE plus Organic Matter.
Hydrocarbons	See NITROGEN TETROXIDE plus Fuels.

Iron	See IRON plus Nitrogen Dioxide.
Magnesium	See MAGNESIUM plus Nitrogen Dioxide.
Manganese	See MANGANESE plus Nitrogen Dioxide.
Methylene Chloride	See NITROGEN TETROXIDE plus 1,2-Dichloroethane.
Olefins	Nitrogen dioxide and olefins form extremely unstable nitrosates or nitrosites. Sabatier & Senderens, *Comp. Rend.* **116:** 756 (1893).
Organic Matter	Mixtures of nitrogen tetroxide and hydrocarbons are high explosives and some combinations are very hazardous.
	Damon (1965).
	See NITROGEN TETROXIDE plus Fuels.
	See NITROGEN TETROXIDE plus Organic Matter.
Ozone	See OZONE plus Nitrogen Dioxide.
Phospham	See PHOSPHAM plus Nitrogen Dioxide.
Phosphorus	See MAGNESIUM plus Nitrogen Dioxide.
Potassium	See MANGANESE plus Nitrogen Dioxide.
Propylene	During an experiment to produce lactic acid by oxidizing propylene with nitrogen tetroxide, a violent explosion occurred. See also NITROGEN TETROXIDE plus Olefins.
	Fawcett (1966). B.B. Brandt, et al., *Khim.*
	Prom. SSSR **3:** 204-10 (1961).
Sodium	See SODIUM plus Nitrogen Peroxide.
Sulfur	See MAGNESIUM plus Nitrogen Dioxide.
Tetrachloroethane	See NITROGEN TETROXIDE plus 1,2-Dichloroethane.
(Asymmetrical)	
1,1,1-Trichloroethane	See NITROGEN TETROXIDE plus 1,2-Dichloroethane.
Trichloroethylene	See NITROGEN TETROXIDE plus 1,2-Dichloroethane.
Tungsten Carbide	See TUNGSTEN CARBIDE plus Nitrogen Dioxide.

NITROGEN SULFIDE

(See SULFUR NITRIDE)

NITROGEN TETROXIDE N_2O_4

Alcohols	An explosion of these materials killed a research worker in a 1955 accident.
	Mellor **8, Supp. 2:** 264 (1967).
Nitrobenzene	Mixtures of nitrogen tetroxide and nitrobenzene qualify as military explosives.
	Mellor **8, Supp. 2:** 264 (1967).
Petroleum	An explosion of these materials killed 17 workers and devastated a plant in Bodio, Switzerland.
	Mellor **8, Supp. 2:** 264 (1967).
	See NITROGEN TETROXIDE plus Fuels.
	See NITROGEN TETROXIDE plus Organic Matter.
Toluene	A mixture of these chemicals caused an explosion at an industrial plant in Zschornewitz.
	Mellor **8, Supp. 2:** 264 (1967).

NITROGEN TRIBROMIDE NBr_3

Arsenic	See ARSENIC plus Nitrogen Tribromide.
Phosphorus	See ARSENIC plus Nitrogen Tribromide.
	See PHOSPHORUS plus Nitrogen Bromide.

NITROGEN TRICHLORIDE NCl_3

Ammonia	Nitrogen trichloride explodes on contact with concentrated ammonia, arsenic, hydrogen sulfide, nitric oxide, organic matter, ozone, phosphine, phosphorus, potassium cyanide, potassium hydroxide, or selenium.
	H. Davy, *Phil. Trans. Roy. Soc. London* **103:** 242 (1813).

	Comp. Rend. **70:** 539. E. Schneider, *Report Anal. Chem.* **1:** 54 (1881).
Arsenic	See ARSENIC plus Nitrogen Trichloride. See HYPOCHLORITES plus Urea.
Dibutyl Ether	During preparation of nitrogen trichloride by bubbling chlorine into an aqueous solution of ammonium sulfate and 100 ml. of the ether, 50 ml. of the ether-NCl_3 mixture over ammonium sulfate solution was stored in a refrigerator. Five minutes later, the mixture exploded violently.
	Chem. Eng. News **44** (31): 46 (1966).
Grease	Nitrogen trichloride is an explosive substance. Even grease from fingers can cause explosion.
	Ann. Chim. et Phys. (1) **86:** 37.
Hydrogen Sulfide	See NITROGEN TRICHLORIDE plus Ammonia.
Nitric Oxide	See NITROGEN TRICHLORIDE plus Ammonia.
Organic Matter	See NITROGEN TRICHLORIDE plus Ammonia.
Ozone	See NITROGEN TRICHLORIDE plus Ammonia.
	See OZONE plus Nitrogen Trichloride.
Phosphine	See NITROGEN TRICHLORIDE plus Ammonia.
Phosphorus	See NITROGEN TRICHLORIDE plus Ammonia.
Potassium Cyanide	See NITROGEN TRICHLORIDE plus Ammonia.
Potassium Hydroxide	See NITROGEN TRICHLORIDE plus Ammonia.
Selenium	See NITROGEN TRICHLORIDE plus Ammonia.

NITROGEN TRIFLUORIDE NF_3

Ammonia	See HYDROGEN plus Nitrogen Trifluoride.
Carbon Monoxide	See HYDROGEN plus Nitrogen Trifluoride.
Diborane	Studies of nitrogen trifluoride and diborane revealed no interaction at room temperature and 1-8 atmospheres pressure. When the mixtures were handled as liquids at low temperatures, violent explosions occurred, even when

	precautions were made to eliminate OF_2 impurities.
	Lawless and Smith, pp. 34-35 (1968).
Hydrogen	See HYDROGEN plus Nitrogen Trifluoride.
Hydrogen Sulfide	See HYDROGEN plus Nitrogen Trifluoride.
Methane	See HYDROGEN plus Nitrogen Trifluoride.
Tetrafluorohydrazine	Several hundred grams of a crude reaction mixture involving nitrogen trifluoride and tetrafluorohydrazine had been collected in a small stainless steel cylinder. During opening of valves to measure cylinder pressure, the cylinder exploded, killing one man and injuring another.
	MCA Case History **683** (1966).

NITROGEN TRIIODIDE NH_3NI_3

(self-reactive)	Nitrogen triiodide explodes under very slight shock.
	Van Dolah (1966). *Chem. Eng. News* **46** (9): 38 (1968). *Latimer and Hildebrand,* p. 202 (1951).
Acids	Addition of concentrated acids causes nitrogen triiodide to explode.
	Ann. Chim. et Phys. (2) **69:** 88. *J. Am. Chem. Soc.* **10:** 332. *Comp. Rend.* **97:** 526.
Bromine	See BROMINE plus Nitrogen Triiodide.
Chlorine	See BROMINE plus Nitrogen Triiodide.
Hydrogen Sulfide	See BROMINE plus Nitrogen Triiodide.
Ozone	See BROMINE plus Nitrogen Triiodide.

NITROGEN TRIOXIDE N_2O_3

Phosphine	Phosphine gas ignites spontaneously if a trace of nitrogen trioxide is added.
	T. Graham, *Edin. Roy. Soc.* **13:** 88 (1835).

NITROGLYCERIN $C_3H_5(ONO_2)_3$

Ozone	See OZONE plus Nitroglycerin.

NITROMETHANE O_2NCH_3

Aluminum Chloride and Organic Matter	See ALUMINUM CHLORIDE plus Nitromethane and Organic Matter.
Calcium Hydroxide	See CALCIUM HYDROXIDE plus Nitroethane.
Calcium Hypochlorite	See CALCIUM HYPOCHLORITE plus Nitromethane.
Hexamethylbenzene	See HEXAMETHYLBENZENE plus Nitromethane.
Hydrocarbons	See NITROETHANE plus Hydrocarbons.
Hydroxides	See CALCIUM HYDROXIDE plus Nitroethane.
Inorganic Bases	See CALCIUM HYDROXIDE plus Nitroethane.
Organic Amines	Nitromethane plus organic amines forms sensitive explosive mixtures. *Van Dolah* (1966).
Potassium Hydroxide	See CALCIUM HYDROXIDE plus Nitroethane.
Sodium Hydroxide	See CALCIUM HYDROXIDE plus Nitroethane.

NITROPARAFFINS

Aluminum Chloride and Organic Matter	See ALUMINUM CHLORIDE plus Nitromethane and Organic Matter.
Calcium Hydroxide	See CALCIUM HYDROXIDE plus Nitroethane.
Hydrocarbons	See NITROETHANE plus Hydrocarbons.
Hydroxides	See CALCIUM HYDROXIDE plus Nitroethane.
Inorganic Bases	See CALCIUM HYDROXIDE plus Nitroethane.
Potassium Hydroxide	See CALCIUM HYDROXIDE plus Nitroethane.
Sodium Hydroxide	See CALCIUM HYDROXIDE plus Nitroethane.

NITROPENTAMMINE COBALT NITRATE

(See COBALTOUS-PENTAMMINE NITRITO-N NITRATE)

o-NITROPHENOL $HO\text{-}C_6H_4\text{-}2NO_2$

Potassium Hydroxide	See POTASSIUM HYDROXIDE plus o-Nitrophenol.

o-NITROPHENYLACETIC ACID $O_2NC_6H_4CH_2COOH$

Thionyl Chloride	See THIONYL CHLORIDE plus o-Nitrobenzoylacetic Acid.

o-NITROPHENYLACETYL CHLORIDE $O_2NC_6H_4CH_2COCl$

(self-reactive)

Two explosions are reported: In one case, the solvent-free residue decomposed violently, generating black smoke and a red flame. In the other case, the residue exploded as soon as the chloroform solvent was evaporated. A similar finding with o-nitrobenzoyl chloride is referenced.

Chem. Eng. News **42** (13):39 (1964).

Chem. Eng. News **23:** 2394 (1945).

J. Am. Chem. Soc. **68:** 344 (1946).

May and Baker Ltd., *Chem. and Ind.* **39** (1946).

m-NITROPHENYLDIAZONIUM PERCHLORATE

$NO_2C_6H_4N(\equiv N)ClO_4$

(self-reactive)

This compound is very sensitive to heat and shock.

ACS **146:** 205. *Davis* (1943).

NITROPROPANE $CH_3CH_2CH_2NO_2$

Calcium Hydroxide	See CALCIUM HYDROXIDE plus Nitroethane.
Hydrocarbons	See NITROETHANE plus Hydrocarbons.
Hydroxides	See CALCIUM HYDROXIDE plus Nitroethane.
Inorganic Bases	See CALCIUM HYDROXIDE plus Nitroethane.
Potassium Hydroxide	See CALCIUM HYDROXIDE plus Nitroethane.
Sodium Hydroxide	See CALCIUM HYDROXIDE plus Nitroethane.

2-NITROPROPANE $CH_3CHNO_2CH_3$

Chlorosulfonic Acid	See CHLOROSULFURIC ACID plus 2-Nitropropane.
Oleum	See OLEUM plus 2-Nitropropane.

NITROSOPHENOL ONC_6H_4OH

Acids	Nitrosophenol explodes on heating or on addition of concentrated acids. *Beilstein*, p. 600 (1909).

NITROSYL AZIDE ONNNN

(self-reactive)	This unstable yellow compound decomposes even at minus 50¡C. *Mellor* **8, Supp. 2:** 22 (1967).

NITROSYL CHLORIDE ONCl

Acetone	Nitrosyl chloride sealed in a tube with a residue of acetone in the presence of platinum catalyst gave an explosive reaction. *Chem. Eng. News* **35** (43): 60 (1957).
Aluminum	See ALUMINUM plus Nitrosyl Chloride.

NITROSYL FLUORIDE ONF

Boron	See BORON plus Nitrosyl Fluoride.
Halogenated Olefin	Excessive quantities of the two reactants in a reaction vessel caused the vessel to explode.
	MCA Case History **928** (1963).
Phosphorus	See BORON plus Nitrosyl Fluoride.
Silicon	See BORON plus Nitrosyl Fluoride.
Sodium	See SODIUM plus Nitrosyl Fluoride.

NITROSYL PERCHLORATE $ONOClO_3$

(self-reactive)	Decomposition of nitrosyl perchlorate begins just below 100¡C. Above 100¡C (115-120¡C) a low order explosion occurs.
	H. Gerding and W.F. Haak, *Chem. Weekblad* **52:** 282-3 (1956).
Acetone	Nitrosyl perchlorate ignites and explodes with acetone.
	Hoffman & Zedtwitz, *Ann. Chem.* **42:** 2031 (1909).
Amines	Explosions occur with mixtures of nitrosyl perchlorate and primary amines. Hoffman & Zedtwitz, *Ann. Chem.* **42:** 2031 (1909).
Cobalt Pentammine	See PHENYL ISOCYANATE plus Cobalt
Triazo Perchlorate	Pentammine Triazo Perchlorate and Nitrosyl
and Phenyl Isocyanate	Perchlorate.
Diethyl Ether	Nitrosyl perchlorate ignites and explodes with diethyl ether.
	Hoffman & Zedtwitz, *Ann. Chem.* **42:** 2031 (1909).
Metal Salts	The hot reaction of nitrosyl perchlorate with metal salts, which is a way to prepare perchorates, forms salts that are very explosive.
	Kirk and Othmer, *Second Ed.* **5:** 69 (1963).

NITROSYLSULFURIC ACID O=$NOSO_2OH$

Dinitroaniline Hydrochloride	An explosion occurred during the diazotization using nitrosylsulfuric acid which resulted in several fatalities. Subsequent tests have shown that this was due to the high concentration of reactants in the mixture.
	MCA Case History **1763** (1971).

p-NITROTOLUENE $O_2NC_6H_4CH_3$

Sulfuric Acid	para-Nitrotoluene and sulfuric acid exploded at 80¡C.
	Chem. Eng. News **27:** 2504.

NITROUS ACID HNO_2

Phosphine	See PHOSPHINE plus Nitrous Acid.
Phosphorus Trichloride	See PHOSPHORUS TRICHLORIDE plus Nitric Acid.

NITROUS OXIDE N_2O

(self-reactive)	This compound decomposes explosively at high temperatures.
	Mellor **8, Supp. 2:** 207 (1967).
Aluminum	See ALUMINUM plus Carbon Disulfide.
Boron	See BORON plus Nitrous Oxide.
Hydrazine	See NITROUS OXIDE plus Lithium Hydride.
Lithium Hydride	Spontaneous ignition occurs when nitrous oxide and lithium hydride or hydrazine are mixed.
	Mellor **8, Supp. 2:** 214 (1967).
Phenyl-Lithium	See PHENYL-LITHIUM plus Nitrous Oxide.

Phosphine	See PHOSPHINE plus Nitrous Oxide.
Sodium	See SODIUM plus Nitrogen Peroxide.
Tungsten Carbide	See TUNGSTEN CARBIDE plus Nitrogen Dioxide.

NITRYL CHLORIDE O_2NCl

Ammonia	Liquid ammonia reacts violently with nitryl chloride, even at minus 75¡C.
	J. Am. Chem. Soc. **74:** 3408-10 (1952).
	Mellor **8, Supp. 1:** 331 (1964).
Stannic Bromide	The reaction between nitryl chloride and stannic bromide or stannic iodide occurs with violence.
	J. Am. Chem. Soc. **74:** 3408 (1952).
Stannic Iodide	See NITRYL CHLORIDE plus Stannic Bromide.
Sulfur Trioxide	Liquid sulfur trioxide reacts violently with nitryl chloride, even at 75¡C.
	J. Am. Chem. Soc. **74:** 3409 (1952).

NITRYL FLUORIDE O_2NF

Phosphorus	See PHOSPHORUS plus Nitryl Fluoride.
Potassium	See POTASSIUM plus Nitryl Fluoride.

NITRYL PERCHLORATE O_2NOClO_3

Acetone	See NITRYL PERCHLORATE plus Benzene.
Benzene	Nitronium perchlorate reacts with benzene, giving a slight explosion and flash. With acetone and diethyl ether, the reaction produces a sharper explosion.
	Chem. Eng. News **38** (15):5 (1960).
Diethyl Ether	See NITRYL PERCHLORATE plus Benzene.
Organic Matter	Nitryl perchlorate reacts with organic matter with a

	violence ranging from slight explosions to sharp detonations accompanied by fire.
	ACS **146:**210. *Can. J. Research* **18** (B):358-62 (1940).

NYLON

Fluorine	See FLUORINE plus Solid Nonmetals and Oxygen.

OLEUM $H_2SO_4SO_3$

Acetic Acid	See ACETIC ACID plus Oleum.
Acetic Anhydride	See ACETIC ANHYDRIDE plus Oleum.
Acetonitrile	See ACETONITRILE plus Oleum.
Acrolein	See ACROLEIN plus Oleum.
Acrylic Acid	See ACRYLIC ACID plus Oleum.
Acrylonitrile	See ACRYLONITRILE plus Oleum.
Allyl Alcohol	See ALLYL ALCOHOL plus Oleum.
Allyl Chloride	See ALLYL CHLORIDE plus Oleum.
2-Aminoethanol	See 2-AMINOETHANOL plus Oleum.
Ammonium Hydroxide	Mixing oleum and 28% ammonium hydroxide in a closed container caused the temperature and pressure to increase.
	Flynn and Rossow (1970). See Note under complete reference.
Aniline	See ANILINE plus Oleum.
n-Butyraldehyde	See n-BUTYRALDEHYDE plus Oleum.
Cresol	See CRESOL plus Oleum.
Cumene	See CUMENE plus Oleum.
Dichloroethyl Ether	See DICHLOROETHYL ETHER plus Oleum.
Diethylene Glycol Monomethyl Ether	See DIETHYLENE GLYCOL MONOMETHYL ETHER plus Oleum.

Diisobutylene	See DIISOBUTYLENE plus Oleum.
Epichlorohydrin	See EPICHLOROHYDRIN plus Oleum.
Ethyl Acetate	See ETHYL ACETATE plus Oleum.
Ethylene Cyanohydrin	Mixing oleum and ethylene cyanohydrin in a closed container caused the temperature and pressure to increase.
	Flynn and Rossow (1970). See Note under complete reference.
Ethylene Diamine	See ETHYLENE DIAMINE plus Oleum.
Ethylene Glycol	See ETHYLENE GLYCOL plus OLEUM.
Ethylene Glycol	See ETHYLENE GLYCOL MONOETHYL
Monoethyl Ether	ETHER ACETATE plus Oleum.
Acetate	
Ethyleneimine	Mixing oleum and ethyleneimine in a closed container caused the temperature and pressure to increase.
	Flynn and Rossow (1970). See Note under complete reference.
Glyoxal	See GLYOXAL plus Oleum.
Hydrochloric Acid	Mixing oleum and 36% hydrochloric acid in a closed container caused the temperature and pressure to increase.
	Flynn and Rossow (1970). See Note under complete reference.
Hydrofluoric Acid	Mixing oleum and 48.7% hydrofluoric acid in a closed container caused the temperature and pressure to increase.
	Flynn and Rossow (1970). See Note under complete reference.
Isoprene	See ISOPRENE plus Oleum.
Isopropyl Alcohol	Mixing oleum and isopropyl alcohol in a closed container caused the temperature and pressure to increase.
	Flynn and Rossow (1970). See Note under complete reference.
Mesityl Oxide	See MESITYL OXIDE plus Oleum.

Methyl Ethyl Ketone	See METHYL ETHYL KETONE plus Oleum.
Nitric Acid	Mixing oleum and 70% nitric acid in a closed container caused the temperature and pressure to increase. *Flynn and Rossow* (1970). See Note under complete reference.
2-Nitropropane	Mixing oleum and 2-nitropropane in a closed container caused the temperature and pressure to increase. *Flynn and Rossow* (1970). See Note under complete reference.
Propiolactone (beta-)	Mixing oleum and propiolactone (beta-) in a closed container caused the temperature and pressure to increase. *Flynn and Rossow* (1970). See Note under complete reference.
Propylene Oxide	Mixing oleum and propylene oxide in a closed container caused the temperature and pressure to increase. *Flynn and Rossow* (1970). See Note under complete reference.
Pyridine	Mixing oleum and pyridine in a closed container caused the temperature and pressure to increase. *Flynn and Rossow* (1970). See Note under complete reference.
Sodium Hydroxide	See SODIUM HYDROXIDE plus Oleum.
Styrene Monomer	Mixing oleum and styrene monomer in a closed container caused the temperature and pressure to increase. *Flynn and Rossow* (1970). See Note under complete reference.
Sulfolane	Mixing oleum and sulfolane in a closed container caused the temperature and pressure to increase. *Flynn and Rossow* (1970). See Note under complete reference.
Vinyl Acetate	Mixing oleum and vinyl acetate in a closed container caused the temperature and pressure to increase. *Flynn and Rossow* (1970). See Note under complete

	reference.
Vinylidene Chloride	Mixing oleum and vinylidene chloride in a closed container caused the temperature and pressure to increase. *Flynn and Rossow* (1970). See Note under complete reference.

ORGANIC MATTER

Acetyl Peroxide	See ACETYL PEROXIDE plus Solvents.
Aluminum Chloride and Nitromethane	See ALUMINUM CHLORIDE plus Nitromethanes and Organic Matter.
Ammonium Nitrate	See AMMONIUM NITRATE plus Organic Matter.
Ammonium Perchlorate	See SULFUR plus Ammonium Perchlorate.
Barium Peroxide	See BARIUM PEROXIDE plus Organic Matter.
Benzoyl Peroxide	See BENZOYL PEROXIDE plus Organic Matter.
Boron Trichloride	See BORON TRICHLORIDE plus Nitrogen Peroxide.
Bromates	See BROMATES plus Organic Matter.
Bromine Monofluoride	See BROMINE MONOFLUORIDE plus Water.
Bromine Pentafluoride	See BROMINE PENTAFLUORIDE plus Acetic Acid.
Bromine Trifluoride	See BROMINE MONOFLUORIDE plus Water.
t-Butyl Peracetate	See t-BUTYL PERACETATE plus Organic Matter.
t-Butyl Perbenzoate	See t-BUTYL PERBENZOATE plus Organic Matter.
Calcium Hypochlorite	See CALCIUM HYPOCHLORITE plus Organic Matter.
Chlorates	See BROMATES plus Organic Matter.
Chloric Acid	See CHLORIC ACID plus Organic Matter. See ANTIMONY plus Chloric Acid.
Chlorine	See BROMINE MONOFLUORIDE plus Water.
Chlorine Dioxide	See CHLORINE DIOXIDE plus Organic Matter.

Chlorine Monoxide	See POTASSIUM plus Chlorine Monoxide.
	See CHLORINE MONOXIDE plus Organic Matter.
Chlorine Trifluoride	See CHLORINE TRIFLUORIDE plus Organic Matter.
	See also BROMINE MONOFLUORIDE plus Water.
Chlorine Trioxide	See CHLORINE TRIOXIDE plus Organic Matter.
Chlorosulfonic Acid	See CHLOROSULFURIC ACID plus Organic Matter.
Chromic Anhydride	See CHROMIC ANHYDRIDE plus Organic Matter.
Diazomethane	See DIAZOMETHANE (self-reactive).
Diisopropyl Peroxydicarbonate	See DIISOPROPYL PEROXYDICARBONATE plus Organic Matter.
Dioxygen Difluoride	See DIOXYGEN DIFLUORIDE plus Organic Matter.
Fluorine	See FLUORINE plus Neoprene.
	See FLUORINE plus Organic Matter.
Fluorine Perchlorate	See FLUORINE PERCHLORATE plus Organic Matter.
Halogen Fluorides	See BROMINE MONOFLUORIDE plus Water; see individual fluoride plus organic matter.
Hydrogen Peroxide	See HYDROGEN PEROXIDE plus Organic Matter.
Hydrogen Peroxide and Sulfuric Acid	See ALCOHOLS plus Hydrogen Peroxide and Sulfuric Acid.
Iodates	See BROMATES plus Organic Matter.
Iodine Heptafluoride	See BROMINE MONOFLUORIDE plus Water.
Iodine Monochloride	See IODINE MONOCHLORIDE plus Organic Matter.
Iodine Pentafluoride	See ARSENIC plus Iodine Pentafluoride.
	See also BROMINE MONOFLUORIDE plus Water.
	See also IODINE PENTAFLUORIDE plus Water.
Iodine Pentoxide	See CARBON plus Iodine Pentoxide.
Liquid Air	See CHARCOAL plus Liquid Air.

Lithium	See LITHIUM plus Organic Matter.
Magnesium Perchlorate	See MAGNESIUM PERCHLORATE plus Organic Matter.
Manganese Heptoxide	See MANGANESE HEPTOXIDE plus Organic Matter.
Mercuric Nitrate	See MERCURIC NITRATE plus Unsaturates; Aromatics.
Nitrate-Nitrite	See ALUMINUM plus Nitrate-Nitrite and Organic Matter.
Nitric Acid	See NITRIC ACID plus Organic Matter.
Nitric Oxide	See NITRIC OXIDE plus Fuels.
Nitroethane	See NITROETHANE plus Hydrocarbons.
Nitrogen Tetroxide	See NITROGEN TETROXIDE plus Organic Matter.
Nitrogen Trichloride	See NITROGEN TRICHLORIDE plus Ammonia; Grease.
Nitromethane	See NITROMETHANE plus Hydrocarbons.
Nitryl Perchlorate	See NITRYL PERCHLORATE plus Organic Matter.
Oxygen	See OXYGEN plus Clothing.
Ozone	See OZONE plus Organic Matter.
Peracetic Acid	See PERACETIC ACID plus Organic Matter.
Perchlorates	See PERCHLORATES plus Organic Matter.
Perchloric Acid	See PERCHLORIC ACID plus Organic Fibers.
Permanganates and Sulfuric Acid	See PERMANGANATES plus Sulfuric Acid and Benzene.
Permanganic Acid	See PERMANGANIC ACID (self-reactive).
Permonosulfuric Acid	See PERMONOSULFURIC ACID plus Cotton; Organic Matter.
Peroxides	See PEROXIDES plus Organic Matter.
Phosphoric Anhydride and Water	See PHOSPHORIC ANHYDRIDE plus Organic Matter and Water.

Phosphorus Oxychloride	See PHOSPHORUS OXYCHLORIDE plus Organic Matter.
Phosphorus Trichloride	See PHOSPHORUS OXYCHLORIDE plus Organic Matter.
Potassium Oxides	See POTASSIUM plus Air.
Potassium Permanganate	See POTASSIUM PERMANGANATE plus Organic Matter.
Sodium Chlorate	See SODIUM CHLORATE plus Organic Matter.
Sodium Chlorite	See SODIUM CHLORITE plus Organic Matter.
Sodium Peroxide	See SODIUM PEROXIDE plus Organic Matter.
Stannous Nitrate	See STANNOUS NITRATE plus Organic Matter.
Sulfur Monochloride	See SULFUR MONOCHLORIDE plus Organic Matter.

ORGANIC PERCHLORATES

(self-reactive)	Almost any organic perchlorate decomposes when heated. The ammoniacal and aminiacal compounds seem more sensitive than the others. The amine perchlorates have explosion temperatures in the range of 250¡ C to 300¡ C. None explodes below 200¡ C. *ACS* **146:** 204-20 (1960).

ORGANIC SULFIDES RSR

Calcium Hypochlorite	See CALCIUM HYPOCHLORITE plus Organic Sulfides.

OSMIUM Os

Chlorine Trifluoride	See ANTIMONY plus Chlorine Trifluoride.
Oxygen Difluoride	See IRIDIUM plus Oxygen Difluoride.

OSMIUM-AMMINE NITRATES

(self-reactive)	Osmium-ammine nitrates may be impact-sensitive. $Os(NH_3)_4O_2(NO_3)_2$ crystals are very unstable.
	Mellor **15:** 727 (1946-1947).

OSMIUM-AMMINE PERCHLORATES

(self-reactive)	Osmium-ammine perchlorates may be impact-sensitive.
	Mellor **15:** 727 (1946-1947).

OXALIC ACID HOCOCOOH

Furfuryl Alcohol	See FURFURYL ALCOHOL plus Oxalic Acid.
Silver	See SILVER plus Oxalic Acid.
Sodium Chlorite	See SODIUM CHLORITE plus Oxalic Acid.
Sodium Hypochlorite	See SODIUM HYPOCHLORITE plus Oxalic Acid.

OXALYL BROMIDE BrCOCOBr

Sodium-Potassium Alloy	See SODIUM-POTASSIUM ALLOY plus Oxalyl Bromide.

OXALYL CHLORIDE ClCOCOCl

Sodium-Potassium Alloy	See SODIUM-POTASSIUM ALLOY plus Oxalyl Bromide.

OXIDES

(See specific oxides, dioxides, trioxides as primary entries or under other reactants)

OXIDIZING AGENTS

Carbides	See CARBIDES plus Oxidizing Agents.

OXODISILANE $H_3SiSiHO$

Air	Oxodisilane is spontaneously flammable in air.
	Z. Anorg. Chemie **117:** 209. *Hurd*, pp. 36, 73 (1952).

OXOSILANE H_2SiO

Air	Oxosilane is spontaneously flammable in air.
	Z. Anorg. Chemie **117:** 209.
	See also CHLORINE plus Oxomonosilane.
Chlorine	See CHLORINE plus Oxomonosilane.

OXYGEN O_2

Aluminum	See ALUMINUM plus Oxygen.
Aluminum Borohydride	Explosive reaction occurs at temperatures as low as 20¡C. Explosive range: 5% to 90%.
	J. Am. Chem. Soc. **71:** 2950.
Aluminum Hydride	Aluminum hydride is spontaneously flammable in oxygen or air.
	Lockheed, p. 8 (1960).
Beryllium Borohydride	Beryllium borohydride reacts explosively with oxygen or water.
	A. J. Stosick, *Acta Crystallogr.* **5** (1): 15 (1952).
Boron Arsenotribromide	In contact with air or oxygen, this material is readily oxidized, and in most cases ignites spontaneously.
	Mellor **9:** 57 (1946-1947).
Boron Decahydride	Boron decahydride ignites spontaneously when exposed to air or oxygen.

	Mellor **5:** 36 (1946-1947).
Boron Trichloride	Oxygen and boron trichloride react vigorously on sparking.
	Mellor **5:** 131 (1946-1947).
Butane and Nickel Carbonyl	See NICKEL CARBONYL plus n-Butane and Oxygen.
Calcium	See CALCIUM plus Oxygen.
Calcium Phosphide	See SULFUR plus Calcium Phosphide.
Cesium	See CESIUM plus Oxygen.
Cesium Hydride	Cesium hydride ignites in oxygen at room temperature.
	Brauer (1965).
Chlorotrifluoroethylene and Bromine	See CHLOROTRIFLUOROETHYLENE plus Oxygen and Bromine.
Clothing	The normal 2-3 per cent oxygen enrichment of air supplied to an air-supplied suit was upset by failure of the air-oxygen mix valve so that the enrichment was 68-76 per cent. A worker who had disconnected supply and exhaust lines removed his helmet and lighted a cigarette. Apparently a spark from the cigarette lighted his oxygen-saturated underwear and also the pressure suit.
	MCA Case History **884** (1963).
Decaborane	Decaborane is spontaneously flammable in oxygen.
	Chem. Safety Data Sheet **SD 84** (1961).
Diborane	Oxygen and diborane form spontaneously explosive mixtures.
	A. T. Whately and R. N. Pease, *J. Am. Chem. Soc.* **76:** 1997-1999 (1954).
Diethyl Ether	See OXYGEN plus Ethers.
Diphenylethylene	An explosion was observed at the auto-oxidation of diphenylethylene with oxygen under high pressure at low temperature.
	H. Staudinger, *Z. Electrochem.* **31:** 549-52 (1925).

Disilane	Disilane, trisilane, or tetrasilane, when mixed with oxygen or air at ordinary temperatures, ignites or explodes.
	Mellor **6:** 232-4 (1946-1947).
Ethers	In the presence of oxygen or air, ethers form peroxides which may explode spontaneously or when heated.
	Haz. Chem. Data (1966). *MCA Case History* **616** (1960).
	Ethyl ether forms peroxides which may explode when heated to about 100¡C.
	Chem. Safety Data Sheet **SD-29** (1965).
	Isopropyl ether, which had stood on the shelf a long time, exploded when the stuck cap on the bottle was freed.
	MCA Case History **603** (1960).
Germanium	See GERMANIUM plus Oxygen.
Hydrazine	Oxygen and hydrazine form explosive mixtures.
	Mellor **8, Supp. 2:** 72 (1967).
Hydrogen	See HYDROGEN plus Air; Oxygen.
Isopropyl Ether	Isopropyl ether tends to react with oxygen from the air to form unstable peroxides which may detonate with extreme violence. Several incidents are cited.
	NSC Newsletter, Chem. Sec. (May 1966).
	See also OXYGEN plus Ethers.
Lithium	See LITHIUM plus Oxygen.
Nickel Carbonyl and	See NICKEL CARBONYL plus n-Butane
Butane	and Oxygen.
Organic Materials	See OXYGEN plus Clothing.
Oxygen Difluoride and	Violent explosions resulted when a spark was
Water	discharged in a mixture containing 25-70% oxygen difluoride in oxygen over water.
	Mellor **2, Supp. 1:** 191 (1956).
Phosphine	This reaction is explosive at ordinary temperatures.

	Mellor **8, Supp. 3:** 281 (1971).
Phosphorus	See PHOSPHORUS plus Oxygen.
Phosphorus Trifluoride	Phosphorus trifluoride does not burn in air, but if it is mixed with oxygen, the gases explode.
	Comp. Rend. **138:** 789. *Mellor* **8:** 995 (1946-1947).
Phosphorus Trioxide	See PHOSPHORUS TRIOXIDE plus Air.
Polyurethane	In the form of foam, polyurethane, and also polyvinyl chloride, have exploded when saturated with liquid oxygen.
	Ind. Saf. Equip., p. 54 (June 1964).
Polyvinyl Chloride	See OXYGEN plus Polyurethane.
Potassium and Carbon Monoxide	See POTASSIUM plus Carbon Monoxide and Oxygen.
Potassium Peroxide	The reaction of oxygen and potassium peroxide is violent at pressures of oxygen as low as 10 mm.
	Mellor **2, Supp. 3:** 1626 (1963).
Rubidium	See RUBIDIUM plus Oxygen.
Selenium	See SELENIUM plus Oxygen.
Sodium Hydride	Sodium hydride in oxygen ignites at 230¡C.
	Mellor **2:** 483 (1946-1947).
Teflon□ (Polytetrafluoroethylene)	Teflon□ ignited at 1,300¡F. in a 5 psia pure oxygen atmosphere, when used as a 20 AWG wire insulation. Polyolefin insulation ignites at about 1,100¡F. under the same conditions.
	N.A. Aviation (1964).
Tetrafluorohydrazine	An explosive reaction of these two chemicals is likely in the presence of organic matter.
	Mellor **8, Supp. 2:** 113 (1967).
Tetrasilane	See OXYGEN plus Disilane.
Titanium Alloy	See TITANIUM ALLOY plus Oxygen.

1,1,1-Trichloroethane	The sides of a 5,000 psi autoclave were bulged by an explosive reaction between oxygen and 1,1,1-trichloroethane when the pressurized mixture was brought up to 100¡C. and 790 psi and allowed to stand for three hours.
	Chem. Eng. News **35** (43): 60 (1957).
Trichloroethylene	The explosion of an oxygen pipe under pressure (400 psi) in a metallurgical factory was apparently due to the remains of trichloroethylene which was used for the previous cleaning of the pipes. Tests showed it was possible to make a stoichiometric mixture of trichloroethylene and oxygen vapors explode.
	U. Weber, *Chim. Ind. (Paris)* **90** (3): 178-83 (1963).
Trisilane	See OXYGEN plus Disilane.

OXYGEN (**LIQUID**) O_2

Aluminum	See ALUMINUM plus Oxygen.
Asphalt	During transfer of liquid oxygen from a factory reservoir to a tanker truck, some of the liquid leaked from a coupling to the asphalt surface below. When the trucker dropped a hammer on this surface, a violent explosion formed a crater 20 inches square by 4 inches deep in the asphalt and broke windows nearby.
	U. Weber, *Chim. Ind. (Paris)* **90** (3); 178-83 (1963).
Benzene	*Liquid* oxygen (LOX) gives an explosive mixture when combined with benzene.
	Kirschenbaum (1956).
Carbon Monoxide	*Liquid* oxygen gives an explosive mixture when combined with *liquid* carbon monoxide.
	Kirschenbaum (1956).
Carbon Tetrachloride	See OXYGEN (LIQUID) plus Chlorinated Hydrocarbons.
Chlorinated Dye Penetrants	See OXYGEN (LIQUID) plus Chlorinated Hydrocarbons.
Chlorinated Hydrocarbons	Several halogenated solvents reacted explosively with

	liquid oxygen when ignited with a high energy source: 1,1,1-trichloroethane, methylene chloride, trichloroethylene, chlorinated dye penetrants, and carbon tetrachloride. The carbon tetrachloride exploded only mildly. Behavior of these chemicals is similar with nitrogen tetroxide.
	Chem. Eng. News **43** (24): 41 (1965).
	BM Report Invest. **6766** (1966)
Cyanogen	*Liquid* oxygen gives an explosive mixture when combined with *liquid* cyanogen.
	Kirschenbaum (1956).
Fuels	Liquid oxygen plus ordinary fuels, hydrocarbons, and many other organic compounds are powerful explosives.
	BM Bull. **472** (1949). *Kirschenbaum* (1956).
	MCA Case Histories **824** (1962) and **865** (1963).
	Houghton (1966).
Hydrazine	Spontaneous ignition occurs when these chemicals are mixed.
	Mellor **8, Supp. 2:** 95 (1967).
Hydrocarbons	See OXYGEN (LIQUID) plus Fuels.
Lithium Hydride	*Liquid* oxygen gives an explosive mixture when combined with lithium hydride.
	Kirschenbaum (1956).
Magnesium	See MAGNESIUM plus Oxygen.
Methane	*Liquid* oxygen gives an explosive mixture when combined with liquid methane.
	Kirschenbaum (1956).
Methylene Chloride	See OXYGEN (LIQUID) plus Chlorinated Hydrocarbons.
Oil	Traces of oil on the ball bearing of a centrifugal pump reacted with liquid oxygen being transferred by the pump. The heat of reaction vaporized the oxygen and the pump burst from pressurization.

	U. Weber, *Chim. Ind. (Paris)* **90** (3): 178-83 (1963).
Paraformaldehyde	*Liquid* oxygen gives an explosive mixture when combined with paraformaldehyde.
	Kirschenbaum (1956).
Titanium	See TITANIUM plus Oxygen.
1,1,1-Trichloroethane	See OXYGEN (LIQUID) plus Chlorinated Hydrocarbons.
Trichloroethylene	See OXYGEN (LIQUID) plus Chlorinated Hydrocarbons.
Wood and Charcoal	In a plant manufacturing liquid and gaseous oxygen, spruce wood flooring encased in iron sheeting was charred by an undetected, smoldering fire started by a welding spark. Subsequent leakage of liquid oxygen saturated the charred wood and a violent explosion resulted.
	U. Weber, *Chim. Ind. (Paris)* **90** (3): 178-83 (1963).

OXYGEN DIFLUORIDE OF_2

Aluminum Chloride	A vigorous reaction occurs between oxygen difluoride and aluminum chloride, arsenic trioxide, chronic oxide, or phosphorus pentoxide.
	Mellor **2, Supp. 1:** 192 (1956).
Ammonia	Oxygen difluoride and ammonia react immediately with white fumes.
	Mellor **2, Supp. 1:** 192 (1956).
Arsenic Trioxide	See OXYGEN DIFLUORIDE plus Aluminum Chloride.
Bromine	See BROMINE plus Oxygen Difluoride.
Carbon Monoxide	See HYDROGEN plus Oxygen Difluoride.
Chlorine	See CHLORINE plus Oxygen Difluoride.
Chlorine and Copper	See CHLORINE plus Oxygen Difluoride.
Chromic Oxide	See OXYGEN DIFLUORIDE plus Aluminum Chloride.
Hydrogen	See HYDROGEN plus Oxygen Difluoride.
Hydrogen Sulfide	Oxygen difluoride and hydrogen sulfide explode on

	mixing.
	Mellor **2, Supp. 1:** 192 (1956).
Iodine	See BROMINE plus Oxygen Difluoride.
Iridium	See IRIDIUM plus Oxygen Difluoride.
Methane	See HYDROGEN plus Oxygen Difluoride.
Osmium	See IRIDIUM plus Oxygen Difluoride.
Oxygen and Water	See OXYGEN plus Oxygen Difluoride and Water.
Palladium	See IRIDIUM plus Oxygen Difluoride.
Phosphorus Pentoxide	See OXYGEN DIFLUORIDE plus Aluminum Chloride.
Platinum	See IRIDIUM plus Oxygen Difluoride.
Rhodium	See IRIDIUM plus Oxygen Difluoride.
Ruthenium	See IRIDIUM plus Oxygen Difluoride.
Silica	Liquid oxygen difluoride and 60/80 mesh silica gel at about 254 mm. pressure and -196¡C. exploded. The presence of moisture was suspected.
	A.G. Streng, *Chem. Rev.* **63** (6):607-624 (1963).
	Chem. Eng. News **43** (7):41 (1965); **43** (15):41 (1965).

OZONE O_8

Aniline	Aniline in an atmosphere of ozone forms as one of the products a white, gelatinous explosive compound, ozobenzene.
	Mellor **1:** 911 (1946-1947).
Benzene	Benzene in an atmosphere of ozone forms formic, acetic, oxalic, and other acids as well as a white gelatinous explosive compound called ozobenzene.
	Mellor **1:** 911 (1946-1947). R.W. Murray, *Acc. Chem. Res.* **1**(10): 313 (1968).
Bromine	Severe explosions occur in attempts to form tribromine octoxide from these reactants.

	Mellor **2, Supp. 1:** 748 (1956).
Diallyl Methyl Carbinol and Acetic Acid	See DIALLYL METHYL CARBINOL plus Ozone and Acetic Acid.
Diethyl Ether	A mixture of ether and ozone forms aldehyde and acetic acid and a heavy liquid, ethyl peroxide, which is explosive.
	Mellor **1:** 911 (1946-1947).
Dinitrogen Pentoxide	Mixtures of ozone and dinitrogen pentoxide are flammable or explosive.
	Mellor **8, Supp. 2:** 276 (1967).
Ethylene	Ozone and ethylene react explosively.
	Berichte **38:** 3837.
	Mellor **1:** 911 (1946-1947).
Hydrogen Bromide	These chemicals react instantaneously, exploding except at low pressure of 2-3 mm mercury.
	Mellor **2, Supp. 1:** 736 (1956).
Hydrogen Iodide	The reaction between these chemicals is even more energetic than between ozone and hydrogen bromide.
	Mellor **2, Supp. 1:** 736 (1956).
Nitric Oxide	Mixtures of nitric oxide and ozone explode even when the quantity of ozone is small.
	Mellor **8:** 432 (1946-1947).
	Mixtures of ozone and nitric oxide explode violently at liquid-air temperatures.
	Mellor **8, Supp. 2:** 164 (1967).
Nitrogen Dioxide	Nitrogen dioxide and ozone react with the evolution of light, and often explode.
	Pinkus & Schulthess, *J. Chem. Phys.* **18:** 366 (1920).
Nitrogen Trichloride	See NITROGEN TRICHLORIDE plus Ammonia.
	A mixture of ozone and nitrogen trichloride will explode.

	Mellor **1:** 911 (1946-1947).
Nitrogen Triiodide	See BROMINE plus Nitrogen Triiodide.
	Ozone and nitrogen triiodide form an explosive mixture.
	Mellor **1:** 911 (1946-1947).
Nitroglycerin	Ozone and nitroglycerin explode on mixing.
	Mellor **1:** 911 (1946-1947).
Organic Liquids	When some organic liquids are dropped into liquid ozone, explosions sometimes result. This phenomenon was observed in ozone that was formed by neutron or gamma-ray excitation of liquid oxygen. Also ozone itself was observed to decompose with small explosions in such an environment.
	F.E. Adley, *Nucl. Sci. Abstr.* **17:** 18 (1962).
Organic Matter	Liquid ozone is particularly likely to explode when it reaches the boiling point of the ozone or when brought in contact with oxidizable substances.
	Mellor **1:** 894 (1946-1947).
Stibine	Stibine and ozone explode at 90¡C.
	Berichte **38:** 3837.
	Mellor **1:** 907 (1946-1947).

PALLADIUM Pd

Aluminum	See ALUMINUM plus Palladium.
Hydrogen and Isopropyl Alcohol	See HYDROGEN plus Palladium and Isopropyl Alcohol.
Oxygen Difluoride	See IRIDIUM plus Oxygen Difluoride.
Sulfur	Sulfur and palladium react with incandescence.
	J. J. Berzelius, *Acad. Handl.* **33:** 175 (1813).

PALLADIUM-AMMINE NITRATES

(self-reactive)	Palladium-ammine nitrates may be impact-sensitive.
	$Pd(NH_3)_2(NO_3)_2$ and Pd $(NH_3)_4(NO_3)_2$ detonate violently when heated.
	Mellor **15:** 685 (1946-1947).

PALLADIUM-AMMINE PERCHLORATES

(self-reactive)	Palladium-ammine perchlorates may be impact-sensitive.
	Mellor **15:** 684 (1946-1947).

PARAFORMALDEHYDE $(HCHO)_n$

Oxygen	See OXYGEN (LIQUID) plus Paraformaldehyde.

PARATHION $(C_2H_5O)_2P(S)OC_6H_4NO_2$

(self-reactive)	When a sample was heated in a small test tube it decomposed and in a few minutes the residue exploded.
	J.B. McPherson and G.A. Johnson, *Agri. Food Chem.* **4** (1): 42 (1956).
Endrin	While a mixture of parathion and endrin were being blended into a petroleum solvent an exothermic reaction occurred which caused some of the solvent to vaporize. The solvent vapor-air mixture exploded. Overheating, possibly caused by mechanical agitation, started the exothermic reaction.
	Doyle (1973).

PENTABORANE (9) B_5H_9

Air	Pentaborane is spontaneously flammable in air.
	Handbook Chem. Phys. (1958). *Sevegin* (1963).

PENTACHLOROETHANE C_2HCl_5

Sodium-Potassium Alloy	See SODIUM-POTASSIUM ALLOY plus Bromoform.

PENTAMETHYLDIALUMINUM HYDRIDE $(CH_3)_3Al_2H(CH_3)_2$

Air	Pentamethyl aluminum hydride is spontaneously flammable in air. *Hurd*, p. 98 (1952).

PENTAMMINOAZIDOCOBALTIC AZIDE $CoN_3(NH_3)_5(N_3)_2$

(See COBALTIC-PENTAMMINE AZIDE)

PENTAMMINOCHLOROCOBALTIC CHLORITE

$Co(NH_3)_5Cl(ClO_2)_2$

(See COBALTIC-PENTAMMINE CHLORITE)

PENTASILVER TRIHYDROXY DIAMIDOPHOSPHATE

(See SILVER DIAMIDOTRIOXYPHOSPHORANE)

PENTOL (3-METHYL-2-PENTEN-4YN-1-OL)

$CH{\equiv}CC(CH_3){=}CHCH_2OH$

Hydrogen	See HYDROGEN plus 1-Pentol.
Sodium Hydroxide	See SODIUM HYDROXIDE plus Pentol.

PERACETIC ACID CH_3COOOH

(See PEROXYACETIC ACID)

"PER" ACIDS (PERFORMIC, PERACETIC, etc.)

Olefins	Reactions between "per" acids and olefins are vigorously exothermic. Means should be provided for dissipation of heat.
	Chem. Eng. News **28:** 418, 3067 (1950).
	See also "PEROXY" ACIDS

PERCAMPHORIC ACID $C_8H_{14}(COOOH)_2$

(See PEROXYCAMPHORIC ACID)

PERCHLORATES

(See also specific perchlorates as primary entries or under other reactants)

Benzene	Certain metal perchlorates recrystallized from benzene or ethyl alcohol can explode spontaneously.
	J. Am. Chem. Soc. **62** (10): 3524 (October 1940).
Calcium Hydride	See BROMATES plus Calcium Hydride.
Charcoal	Perchlorates explode when melted with reducing agents or when projected into red-hot charcoal.
	Berichte **39:** 3146.
Ethyl Alcohol	See PERCHLORATES plus Benzene.
Metals	When perchlorates are mixed with finely divided metals, the mixture may be explosive.
	ACS **146:** 188. *Lab. Govt. Chemist* (1965).
Organic Matter	Perchlorates will render organic matter easily flammable. When perchlorates are mixed with finely divided organic matter, they may be explosive.
	ACS **146:** 188. *Lab. Govt. Chemist* (1965).
Reducing Agents	See PERCHLORATES plus Charcoal.
Strontium Hydride	See BROMATES plus Strontium Hydride.
Sulfur	See SULFUR plus Perchlorates.
Sulfuric Acid	A mixture of the two may cause an explosion.

Pieters, p. 30 (1957).

PERCHLORIC ACID $HClO_4$

(self-reactive)	Anhydrous perchloric acid can decompose explosively at atmospheric pressure. On storage even in the dark, the anhydrous acid becomes discolored owing to decomposition products, e.g. chlorine dioxide, and may explode spontaneously.
	ACS **146:** 190.
	After an animal carcass was dissolved in nitric acid, fat was skimmed off and 125 milliliters of perchloric acid was added. The sample was heated on a hot plate to dryness in a 1-liter beaker after which two samples were placed on a stainless steel steam tray (steam off). When the samples were touched, they exploded.
	Chem. Eng. News. **51** (6): 29 (Feb. 5, 1973).
Acetic Acid	Explosions involving these materials have occurred in electrolytic polishing baths. The violence in some cases approached that of a true high explosive.
	ACS **146:** 193. *Rev. Met.* **46:** 549-60 (1949).
	Mem. Poudres **32:** 179-96 (1950). *Report L.A. Fire Department. NFPA Quarterly* **40** (4): 275-78 (April 1947).
Acetic Acid and	Mixtures of these three ingredients have varying
Acetic Anhydride	degrees of sensitivity to shock. Vapors above the heated mixtures are flammable.
	ACS **146:** 193-4. *Rev Met.* **46:** 549-60 (1949).
	Mem. Poudres **32:** 179-96 (1950).
Acetic Anhydride	An electropolishing mixture of 170 gallons of 68-72% perchloric acid and 70 gallons of acetic anhydride exploded with devastating effect some time after the refrigerative temperature control of the tank had been turned off. A plastic holder had been inserted into the solution just before the explosion.
	ACS **146:** 187. *BM Explos. Div. Rep.* **3034-C-443** (1947).

	The addition of acetic anhydride to an aqueous solution of perchloric acid causes the formation of acetic acid which can react violently with the perchloric acid.
	Rev. Met. **46** (8): 549-560 (1949).
	Mem. Poudres **32:** 179-196 (1950).
Alcohols	The contact of hot, concentrated perchloric acid with alcohols or cellulose is particularly dangerous.
	ACS **146:** 189, 195. E. M. Harris, *Chem. Eng.* **56** (1):116-7 (1949).
Aniline and	Aniline treated with perchloric acid, then
Formaldehyde	formaldehyde, gives a resinous condensation product which burns with explosive violence.
	Aniline, p. 85 (1964). *U. S. Pat.* 2,871,224.
Antimony Compounds	See ANTIMONY COMPOUNDS (trivalent)
(trivalent)	plus Perchloric Acid.
Bismuth	See BISMUTH plus Perchloric Acid.
Cellulose	See PERCHLORIC ACID plus Alcohols.
Charcoal	A drop of anhydrous perchloric acid on charcoal causes a violent explosion.
	ACS **146:** 188.
Dibutyl Sulfoxide	A 70% perchloric acid solution reacts instantly and explosively on contact with dibutyl sulfoxide.
	Wischmeyer (1973).
Diethyl Ether	A drop of anhydrous perchloric acid in ether causes a violent explosion.
	ACS **146:** 188. *Am. Chem. J.* **23:** 444 (1900).
Dimethyl Sulfoxide	See DIMETHYL SULFOXIDE plus Perchloric Acid.
Ethyl Alcohol	In mineral analysis the potassium cation is sometimes identified by adding perchloric acid in the presence of ethyl alcohol concentration. Explosions frequently occur that are due to the spontaneous decomposition of ethyl perchlorate formed during concentration and of residual perchloric acid. With methyl alcohol, the reaction is identical except

	that the methyl perchlorate that is formed is very explosive.
	Analyst **80:** 10 (1955).
Fluorine	See FLUORINE plus Perchloric Acid.
Glycerine and Lead Oxide	See LEAD OXIDE plus Glycerine and Perchloric Acid.
Glycol Ethers	Glycol ethers, glycols, ketones, and alcohols undergo violent decomposition in contact with 68-72% perchloric acid.
	ACS **146:** 195. *U.S. Patent* 2,504,119.
Glycols	See PERCHLORIC ACID plus Glycol Ethers.
Hydriodic Acid	Perchloric acid ignites with hydriodic acid.
	Am. Chem. J. **23:** 444 (1900).
Hydrochloric Acid	See HYDROCHLORIC ACID plus Perchloric Acid.
Hydrogen	The explosion temperature of hydrogen-perchloric acid vapor mixtures is lowered from 400 to 215¡ C by the presence of steel particles.
	ACS **146:** 189. *Angew. Chem.* **52:** 616-18 (1939).
Hypophosphites	See HYPOPHOSPHITES plus Perchloric Acid.
Ketones	See PERCHLORIC ACID plus Glycol Ethers.
Methyl Alcohol	See PERCHLORIC ACID plus Ethyl Alcohol.
Nitrogen Iodide	See NITROGEN TRIIODIDE plus Acids.
Nitrosophenol	See NITROSOPHENOL plus Acids.
Organic Matter	Perchloric acid can cause fire or explosion in most organic materials. Example: When bis(2-hydroxyethyl)-terephthalate, being refluxed with 5% perchloric acid in ethyl alcohol, was allowed to go to dryness, there was a violent explosion. A similar mixture, containing also ethylene glycol, flashed brightly after 18 hours refluxing. See also the other organic entries under perchloric acid.
	Wheeler (1969).
Paper	A drop of anhydrous perchloric acid on paper can cause a

	violent explosion.
	ACS **146:** 188.
Phosphorus Pentoxide	See PERCHLORIC ACID plus Sulfuric Acid.
Phosphorus Pentoxide and Chloroform	See PHOSPHORUS PENTOXIDE plus Perchloric Acid and Chloroform.
Sodium Iodide	See SODIUM IODIDE plus Perchloric Acid.
Steel	Explosions may occur when 72 percent perchloric acid is used for determination of chromium in steel. These explosions are apparently due to the formation of mixtures of perchloric acid vapor and hydrogen, catalyzed by the presence of steel particles. The presence of steel burnings lowered the explosion temperatures of such mixtures to 215¡ C. Addition of a little water to keep their boiling temperature at 150 to 160¡ C prevented the formation of explosive gas mixtures.
	ACS **146,** p. 189 (1960).
Sulfoxides	See SULFOXIDES plus Perchloric Acid.
Sulfuric Acid	It is fairly easy to produce the dangerous anhydrous perchloric acid from either its salts or its aqueous solutions by heating with high-boiling acids and dehydrating agents such as sulfuric acid and phosphorus pentoxide.
	NSC Data Sheet **D-311.** *ACS* **146:** 71.
	Pascal **16:** 298 (1931-1934).
Sulfur Trioxide	The reaction of anhydrous perchloric acid with sulfur trioxide is violent and accompanied by the evolution of considerable heat, even when diluted with an inert solvent such as chloroform.
	Pascal **16:** 300-303 (1931-1934).
Wood	A drop of anhydrous perchloric acid on wood fibers or dust causes a violent explosion. See also PERCHLORIC ACID plus Cellulose or plus Paper.
	ACS **146:** 188.
	Gordon, Young & Campbell, *Science* **104:** 353 (1946).

PERCHLORYL FLUORIDE $FClO_3$

Benzene and Aluminum Chloride	During the synthesis of perchloryl benzene by the action of perchloryl fluoride on benzene in the presence of aluminum chloride, there also forms a hazardous nitration product which may explode. The product is apparently nitrochlorobenzene, which is shock-sensitive.
	Chem. Eng. News **38** (4): 62 (1960).
Sodium Methylate	Sodium methylate, as it was being added to a mixture of perchloryl fluoride and methyl alcohol, underwent an explosive reaction with perchloryl fluoride in the vapor phase above the liquid. When the sodium methylate and methyl alcohol were mixed before the addition of perchloryl fluoride, no explosion occurred.
	Chem. Eng. News **37** (28): 60 (1959).

PERCHLORYL FLUOROXIDE $FOClO_3$

(See FLUORINE PERCHLORATE)

PERCHROMATES

Aniline	A mixture of aniline and a perchromate gives rise to an explosive reaction as the temperature is increased.
	RŸst and Ebert, p. 297 (1948).
Pyridine	Heating a mixture of pyridine and a perchromate can lead to an explosion.
	RŸst and Ebert, p. 297 (1948).
Quinoline	Heating a mixture of quinoline and perchromate can produce an explosion.
	RŸst and Ebert, p. 297 (1948).

PERFLUOROPROPIONYL FLUORIDE F_3CCF_2COF

Fluorine	An explosion occurred during the investigation of a new method of forming perfluoropropionyl hypofluorite. The method involved cooling the reactor to minus 50¡ C after which a 50-50 fluorine-nitrogen mixture was added to perfluoropropionyl fluoride. It is possible that a small amount of water, which may have been introduced due to the low temperature, converted some of the perfluoropropionyl fluoride to the perfluoropropionic acid, a precursor for the formation of one of the acyl hypofluorites. The latter are known to be explosive.
	MCA Case History **1045** (1966).
	See FLUORINE plus Perfluropropionyl Fluoride.

PERFLUOROSUCCINAMIDE $F_2NCOCF_2CF_2CONF_2$

Lithium Aluminum Hydride and Water	See LITHIUM ALUMINUM HYDRIDE plus Perfluorosuccinamide and Water.

PERFORMIC ACID OCHOOH

(See PEROXYFORMIC ACID)

PERIODATES $MeIO_4$

(self-reactive)	The metaperiodates ($MeIO_4$) in some cases decompose with explosive violence when strongly heated. Ammonium periodate may explode even on gentle friction, e.g., when touched with a spatula.
	Ellern, p. 288 (1968). *Remy* **1:** 814 (1956).

PERIODIC ACID HIO_4

Dimethyl Sulfoxide	See DIMETHYL SULFOXIDE plus Periodic Acid.

PERMANGANATES

(See also specific permanganates as primary entries or see under other reactants)

Acetic Acid	Acetic acid or acetic anhydride can explode with permanganates if not kept cold.
	Von Schwartz, p. 34 (1918).
Acetic Anhydride	See PERMANGANATES plus Acetic Acid.
Sulfuric Acid and	Explosions can occur when permanganates
Benzene	that have been treated with sulfuric acid come in contact with benzene, carbon disulfide, diethyl ether, ethyl alcohol, petroleum, or organic matter.
	Von Schwartz, p. 327 (1918).

PERMANGANIC ACID $HMnO_4$

(self-reactive)	Above 3¡ C permanganic acid is unstable and decomposes explosively. It is a violent oxidant and the following classes of organic chemicals explode into flame on contact with it: alcohols, alkanes, aryl hydrocarbons, greases, cycloalkanes, alkylamines, amides, and ethers. Carbon tetrachloride, chloroform and dichloromethane do not burn.
	J. Am. Chem. Soc. **91** (22): 6200-6201 (1969).
	Chem. Abst. **72:** 17982f (1970).
Ethyl Alcohol	Alcohols should not be mixed with permanganic acid, as they may spontaneously explode.
	Bahme, p. 9 (1961).
Organic Matter	See PERMANGANIC ACID (self-reactive).

PERMONOSULFURIC ACID (**CARO'S ACID**) H_2SO_5

Acetone	Inadvertent addition of acetone to a solution containing permonosulfuric acid resulted in a violent explosion. The permonosulfuric acid had been formed by reaction between hydrogen peroxide and sulfuric acid during an analytical procedure.
	Wood (1966). *NSC Newsletter, Chem. Sec.* (1961). *J. Am.*

	Chem. Soc. **59:** 552-7 (1937).
Alcohols	Permonosulfuric acid in contact with primary or secondary alcohols often produces explosions.
	J. Am. Chem. Soc. **59:** 552 (1937).
Cotton	If 92% permonosulfuric acid is brought in contact with cotton, in a few seconds there is a violent reaction accompanied by a yellow flame.
	Z. Angew. Chem. **22:** 1713.
Manganese Dioxide	The decomposition of 92% permonosulfuric acid is explosive in the presence of smooth or finely divided manganese dioxide or silver.
	Z. Angew. Chem. **22:** 1713.
Organic Matter	Too concentrated permonosulfuric acid in any organic medium may prove dangerous.
	J. Am. Chem. Soc. **59:** 552 (1937).
Platinum	See PLATINUM plus Permonosulfuric Acid.
Silver	See PERMONOSULFURIC ACID plus Manganese Dioxide.

PEROXIDES ROOR

(See specific peroxides or see under other reactants)

Organic Matter	Peroxides may cause ignition of organic materials.
	Lab. Govt. Chemist (1965).
Thiocyanates	See THIOCYANATES plus Oxidizing Agents.

PEROXYACETIC ACID CH_3COOOH

Acetic Anhydride	Acetic anhydride and peracetic acid react readily to form acetyl peroxide which is an extremely sensitive explosive.
	MCA Case History **1795** (1971).
	See also HYDROGEN PEROXIDE plus Acetic Anhydride.

Olefins	See "PER" ACIDS plus Olefins.
Organic Matter	Upon contact with peracetic acid, organic materials can ignite or result in explosions. *Haz. Chem. Data*, p. 214 (1973).

"PEROXY" ACIDS (PERFORMIC, PERACETIC, etc.)

(self-reactive)	Peracids should be handled only in small quantities and with extreme care when pure or very concentrated. Organic peracids, such as peracetic acid, are so unstable that they may explode during distillation, even under reduced pressure. *Kirk and Othmer, Second Ed.* **14:** 809 (1963). *Grignard* **11:** 90 (1935-1954).

PEROXYCAMPHORIC ACID $C_3H_{14}(COOOH)_2$

(self-reactive)	Percamphoric acid explodes when heated rapidly from 80 to 100¡ C. *Chem. Reviews* **45:** 15 (1949).

PEROXYTRICHLOROACETIC ACID $Cl_3CCOOOH$

(self-reactive)	Pertrichloroacetic acid is very unstable. Decomposition products include phosgene, chlorine, hydrochloric acid and carbon monoxide. *Chem. Reviews* **45** (1): 10 (1949).

PEROXYFORMIC ACID OCHOOH

(self-reactive)	Performic acid is an unstable compound capable of undergoing rapid, spontaneous exothermal decomposition at room temperature, even in the absence of foreign substances. It is shock sensitive. *Chem. Eng. News* **28:** 3067 (Sept. 4, 1950).

	Chem. Reviews **45:** 4, 7 (1949).
	Chem. Eng. News **30:** 3041 (1952).
Aluminum	See ALUMINUM plus Performic Acid.
Aniline	Aniline is oxidized violently by performic acid when the acid strength is more than 60% by weight.
	Berichte **48:** 1139 (1915).
Benzaldehyde	Benzaldehyde is oxidized violently by performic acid.
	Berichte **48:** 1139 (1915).
Formaldehyde	Formaldehyde is oxidized violently by concentrated performic acid.
	Berichte **48:** 1139 (1915).
Lead Dioxide	A concentrated solution of performic acid can explode upon contact with powdered lead dioxide.
	Berichte **48:** 1139 (1915).
Magnesium	See MAGNESIUM plus Performic Acid.
Metal Oxides	See METAL OXIDES plus Performic Acid.
Metals	See METAL plus Performic Acid.
Nickel	See NICKEL plus Performic Acid.
Olefins	See "PER" ACIDS plus Olefins.
Phosphorus	See PHOSPHORUS plus Performic Acid.
Sodium Nitride	Sodium nitride can decompose performic acid explosively.
	Berichte **48:** 1139 (1915).
Zinc	See ZINC plus Performic Acid.

PERSULFATES

(See specific persulfates as primary entries or see under other reactants)

PERTRICHLOROACETIC ACID $Cl_3CCOO.OH$

(See PEROXYTRICHLOROACETIC ACID)

PETROLEUM

Nitrogen Tetroxide	See NITROGEN TETROXIDE plus Petroleum.

PHENOL C_6H_5OH

Aluminum Chloride and Nitrobenzene	See ALUMINUM CHLORIDE plus Nitrobenzene and Phenol.
Butadiene	Reaction of the two ingredients, catalyzed by boron trifluoride diethyletherate, and in a petroleum ether solution, pressurized the capped bottle, causing the bottle to explode. *MCA Case History* **790** (1962).
Calcium Hypochlorite	See CALCIUM HYPOCHLORITE plus Phenol.

PHENOL-FORMALDEHYDE RESIN

Fluorine	See FLUORINE plus Solid Nonmetals and Oxygen.

PHENOLS

Acetaldehyde	See ACETALDEHYDE plus Acid Anhydrides.

b-PHENYLBORACYCLOPENTANE $C_6H_5B(CH_2)_4$

Air	Phenyl cyclotetramethylene borine is spontaneously flammable in air. *Douda* (1966).

PHENYL CHLORIDE

(See CHLOROBENZENE)

PHENYLCHLORODIAZIRINE

(See BENZENEDIAZONIUM CHLORIDE)

PHENYL CYCLOTETRAMETHYLENE BORINE

(See b-PHENYLBORACYCLOPENTANE)

PHENYL DIAZOSULFIDE

(See DIPHENYL DIAZOSULFIDE)

PHENYL DICYCLOPENTADIENYL VANADIUM

(See PHENYLVANADOCENE)

p-PHENYLENEDIAMINE PERCHLORATE $C_6H_4(NH_2)_2•ClO_4$

(self-reactive)	This compound was believed in 1910 to be the most powerful explosive substance known. *ACS* **146:** 213. *Berichte* **43:** 2624-30 (1910).

PHENYLHYDRAZINE $C_6H_5NHNH_2$

Lead Dioxide	See LEAD DIOXIDE plus Phenylhydrazine.

n-PHENYLHYDROXYLAMINE HYDROCHLORIDE

$C_6H_5NHOH•HCl$

(self-reactive)	In an attempt to stabilize some phenylhydroxylamine for safekeeping, 700 grams were made into the hydrochloride, but after it had been in the laboratory about two weeks, it exploded with considerable force. *Wallace* (1966).

PHENYL ISOCYANATE C_6H_5NCO

Cobalt Pentammine Triazo Perchlorate and Nitrosyl Perchlorate.	The reaction mixture was stirred and proceeded normally for 2-3 minutes. When stirring was interrupted, the mixture exploded. *Chem. Eng. News* **46** (8): 39 (1968).

PHENYLLITHIUM C_6H_5Li

Air	Phenyl lithium is spontaneously flammable in air. *Ellern* (1961).
Nitrous Oxide	The reaction of phenyl-lithium produces unstable lithium phenylazoxide as a product. *Mellor* **2, Supp. 2:** 93 (1961).

1-PHENYL-2-METHYL-PROPYL ALCOHOL

(See 2-METHYL-3-PHENYL-1-PROPANOL)

PHENYLSILVER C_6H_5Ag

(self-reactive)	Phenyl silver is explosive at room temperature. *Coates,* p. 173 (1956).

PHENYL SULFIDE SALTS

Diazonium Salts	See DIAZONIUM SALTS plus Thiophenates.

PHENYLVANADOCENE $(C_5H_5)_2VC_6H_5$

Air	Phenyl dicyclopentadienyl vanadium is spontaneously flammable in air.

Zeiss, p. 234 (1960).

PHOSGENE $OCCl_2$

Aluminum	See ALUMINUM plus Phosphorus Trichloride.
tert-Butyl Azidoformate	See tert-BUTYL AZIDOFORMATE plus Phosgene.
2, 4-Hexadiyn-1, 6-Diol	Phosgene and 2, 4-hexadiyn-1, 6-diol react to form 2, 4-hexadiyn-1, 6-bischloroformate, which is a shock-sensitive compound.
	P. E. Driedger and H. V. Isaacson, *Chem. Eng. News* **50** (12): 51 (1972).
Isopropyl Alcohol	See ISOPROPYL ALCOHOL plus Phosgene.
Potassium	See POTASSIUM plus Phosgene.
Sodium	See SODIUM plus Phosgene.

PHOSPHAM PN_2H

Air	Phospham ignites in air at slightly elevated temperatures and burns with a white flame.
	H. Rose, *Ann. Phys.* **52:** 62 (1841).
Cupric Oxide	A mixture of phospham and cupric oxide or mercuric oxide decomposes with incandescence.
	Wohler & Liebig, *Ann. Chem.* **11:** 139 (1834).
Mercuric Oxide	See PHOSPHAM plus Cupric Oxide.
Nitrates	See NITRATES plus Phospham.
Nitrogen Dioxide	Phospham ignites in nitrogen dioxide (nitrogen peroxide) vapors.
	H. Rose, *Ann. Phys.* **24:** 308 (1832).

PHOSPHATES

Magnesium	See MAGNESIUM plus Phosphates.

PHOSPHIDES

(See specific phosphides as primary entries or see under other reactants)

PHOSPHINE PH_3

Air	Dry phosphine is spontaneously flammable in cold air.
	H. Rose, *Ann. Phys.* **14:** 183 (1828). *Z. Anorg. Chemie* **180:** 32. *Handbook Chem. Phys.* **40:** 582 (1958). *MCA Case History* **1066** (1965).
	See also PHOSPHINES plus Air.
Boron Trichloride	See BORON TRICHLORIDE plus Nitrogen Peroxide.
Bromine	See BROMINE plus Phosphine.
Chlorine	See BROMINE plus Phosphine.
Chlorine Monoxide	See CHLORINE MONOXIDE plus Phosphine.
Mercuric Nitrate	See MERCURIC NITRATE plus Phosphine.
Nitric Acid	Phosphine is violently decomposed by concentrated nitric acid, and flame is produced.
	Warm fuming nitric acid, dropped in a container of phosphine gas, produces an explosion.
	T. Graham, *Edin. Roy. Soc.* **13:** 88 (1835).
Nitric Oxide	Phosphine plus nitric oxide can be ignited by the addition of oxygen.
	Berzelius **1, i:** 485 (1825).
Nitrogen Trichloride	See NITROGEN TRICHLORIDE plus Ammonia.
Nitrogen Trioxide	See NITROGEN TRIOXIDE plus Phosphine.
Nitrous Acid	Phosphine gas ignites spontaneously if a trace of nitrous acid is added.
	T. Graham, *Edin. Roy. Soc.* **13:** 88 (1835).
Nitrous Oxide	A mixture of nitrous oxide and phosphine can be exploded by a spark.

	Comp. Rend. **18:** 652.
Oxygen	See OXYGEN plus Phosphine.
Potassium and Ammonia	See POTASSIUM plus Phosphine and Ammonia.
Silver Nitrate	See SILVER NITRATE plus Phosphine.

PHOSPHINES PH_3; P_2H_4; $(P_2H_4)_3$; PxHy

(self-reactive)	The higher phosphines (beyond Diphosphine) decompose rapidly in light at room temperature.
	Mellor **8, Supp. 3:** 274 (1971).
Air	If the P_2H_4 is removed by passing the PH_3 and P_2H_4 through concentrated sulfuric acid, the P_2H_4 does not catch fire in air below 150¡C. The PH_3 is spontaneously flammable in cold air. Solid $(P_2H_4)_3$ ignites at 160¡C.
	Z. Anorg. Chemie **180:** 32. *Handbook Chem. Phys.* **40th Ed.:** 582 (1958).

PHOSPHONITRILE AZIDE-TRIMER

(self-reactive)	This is a highly explosive compound, readily detonated by friction.
	Mellor **8, Supp. 2:** 23 (1967).

PHOSPHONIUM IODIDE PH_4I

Bromates	See BROMATES plus Phosphonium Iodide.
Bromic Acid	Phosphonium iodide ignites at ordinary temperatures in contact with bromic, chloric or iodic acid.
	Ann. Chim. et Phys. (2) **47:** 87.
Chlorates	See PHOSPHONIUM IODIDE plus Bromates.
Chloric Acid	See PHOSPHONIUM IODIDE plus Bromic Acid.

Iodates	See PHOSPHONIUM IODIDE plus Bromates.
Iodic Acid	See PHOSPHONIUM IODIDE plus Bromic Acid.
Nitric Acid	Phosphonium iodide ignites spontaneously when mixed with nitric acid at ordinary temperatures. *Ann. Chim. et Phys.* (2) **47:** 87.
Silver Nitrate	Phosphonium iodide reacts vigorously with dry silver nitrate with development of much heat. *Ann. Chim. et Phys.* (2) **47:** 87.

PHOSPHONIUM PERCHLORATE $2PH_3 \cdot 3HClO_4$

(self-reactive)	Violent explosions have occurred in spite of every precaution. *Helv. Chim. Acta* **17:** 222-4 (1934). This is a very explosive salt and cannot be dried. *Mellor* **8, Supp. 3:** 274 (1971).

PHOSPHORIC ANHYDRIDE P_2O_5

(See PHOSPHORUS PENTOXIDE)

PHOSPHORUS P

Air	White (yellow) phosphorus ignites spontaneously in air — even in a rarefied atmosphere. A. D. Backe, *Schweigger's Jour.* **63:** 478 (1831). *Latimer and Hildebrand*, p. 210 (1940).
Alkaline Hydroxides	Phosphorus boiled with alkaline hydroxides yields mixed phosphines which may ignite spontaneously in air. *Z. Anorg. Chemie* **121:** 73. *Sidgwick* **1:** 729 (1950). See PHOSPHORUS plus Potassium Hydroxide.
Ammonium Nitrate	A mixture of white (or yellow) phosphorus and ammonium

	nitrate can be exploded by percussion.
	J. W. Slater, *Chem. Gaz.* **11:** 329 (1853).
Antimony Pentafluoride	Phosphorus ignites in contact with antimony pentafluoride.
	Mellor **9:** 467 (1946-1947).
Barium Bromate	See PHOSPHORUS plus Bromates.
Barium Chlorate	See PHOSPHORUS plus Bromates.
Barium Iodate	See PHOSPHORUS plus Bromates.
Beryllium	See BERYLLIUM plus Phosphorus.
Boron Triiodide	See BORON TRIIODIDE plus Phosphorus. White or red phosphorus and boron triiodide react with incandescence.
	Mellor **5:** 136 (1946-1947).
Bromates	A combination of finely divided phosphorus with finely divided bromates (also chlorates or iodates) of barium, calcium, magnesium, potassium, sodium, or zinc will explode with heat, percussion, and, sometimes, light friction.
	Mellor **2:** 310 (1946-1947).
Bromine	See BROMINE plus Phosphorus.
Bromine Trifluoride	See ANTIMONY plus Bromine Trifluoride.
Bromoazide	See ANTIMONY plus Bromoazide.
Calcium Bromate	See PHOSPHORUS plus Bromates.
Calcium Chlorate	See PHOSPHORUS plus Bromates.
Calcium Iodate	See PHOSPHORUS plus Bromates.
Cerium	See CERIUM plus Phosphorus.
Cesium	Phosphorus reacts vigorously below 250¡C with any of the following materials: cesium, lithium, potassium, rubidium, sodium, sulfur.
	Mellor **8, Supp. 3:** 228 (1971).
Cesium Acetylene	Cesium acetylene carbide becomes incandescent

Carbide	when warmed in contact with phosphorus.
	Mellor **5:** 848-50 (1946-1947).
Cesium Nitride	See CESIUM NITRIDE plus Air.
Charcoal and Air	Phosphorus sprinkled with animal charcoal ignites at 15.5¡C. in the open air.
	Mellor **8:** 771 (1946-1947).
Chlorates	A mixture of red phosphorus and chlorates bursts into flames after a few moments. Moist chlorates explode on contact with white phosphorus.
	Mellor **2, Supp. 1:** 584 (1956).
	See PHOSPHORUS plus Bromates. See PHOSPHORUS plus Potassium Chlorate.
Chlorine	Phosphorus burns spontaneously in gaseous chlorine.
	Mellor **2:** 92, 95; **9:** 626 (1946-1947).
	Phosphorus (white or yellow) burns in chlorine gas with a pale green light. Red phosphorus reacts with chlorine at ordinary temperatures. Finely divided red phosphorus ignites spontaneously in chlorine at ordinary temperatures.
	Moissan, p. 125 (1900).
	The reaction of phosphorus and chlorine, fluorine, or bromine is highly exothermic.
	All can explode in contact with white phosphorus.
	Mellor **8, Supp. 3:** 228 (1971).
	The reaction of white phosphorus and liquid chlorine is explosive.
	Mellor **2, Supp. 1:** 379 (1956).
Chlorine Dioxide	Phosphorus ignites spontaneously in chlorine dioxide and may explode.
	Mellor **2:** 289 (1946-1947).
Chlorine and Heptane	Flaming occurs when liquid chlorine in heptane is added to red phosphorus at 0¡ C.

	Mellor **2, Supp. 1:** 379 (1956).
Chlorine Monoxide	See POTASSIUM plus Chlorine Monoxide.
Chlorine Trifluoride	See ANTIMONY plus Chlorine Trifluoride.
Chlorine Trioxide	Ordinary phosphorus (white or yellow) reacts explosively with chlorine trioxide.
	Ann. Chim. et Phys. (3) **7:** 298.
Chlorosulfonic Acid	Yellow phosphorus reacts feebly with chlorosulfonic acid if cold. At temperatures from 25¡ to 30¡ C., the reaction begins vigorously (with evolution of hydrogen chloride and sulfur dioxide) and ends with an explosion. With red phosphorus a higher temperature is necessary to start the reaction.
	Berichte **15:** 417.
Chromic Acid	See PHOSPHORUS plus Chromium Trioxide.
Chromic Anhydride	See PHOSPHORUS plus Chromium Trioxide.
Chromium Trioxide	Phosphorus reacts explosively with molten chromium trioxide.
	Ann. Chim. et Phys. (6) **5:** 468.
	Mellor **11:** 234 (1946-1947).
Chromyl Chloride	Chromyl chloride explodes with moistened phosphorus. (Light is emitted at the same time.)
	Ann. Chim. et Phys. (2) **31:** 435. *Comp. Rend.* **5:** 753. T. Thomson, *Phil. Trans. Roy. Soc. London* **117:** 195 (1827).
Copper	See COPPER plus Phosphorus.
Cyanogen Iodide	Phosphorus (molten) plus cyanogen iodide reacts with incandescence to produce phosphorus iodide.
	F. Wohler, *Gilbert's Ann.* **69:** 281 (1821).
Fluorine	See FLUORINE plus Phosphorus.
Iodates	See PHOSPHORUS plus Bromates. See PHOSPHORUS plus Potassium Iodate.
Iodine	See IODINE plus Phosphorus.
Iodine Monobromide	Phosphorus reacts violently with molten iodine

	monobromide or iodine monochloride.
	Mellor **8, Supp. 3:** 264.
Iodine Monochloride	See PHOSPHORUS plus Iodine Monobromide.
Iodine Pentafluoride	See ARSENIC plus Iodine Pentafluoride.
Iron	See COPPER plus Phosphorus.
Lanthanum	See CERIUM plus Phosphorus.
Lead Dioxide	When lead dioxide and red phosphorus are ground the mass ignites; with yellow phosphorus, there is an explosion.
	Mellor **7:** 690 (1946-1947).
Lithium	See LITHIUM plus Arsenic. See also PHOSPHORUS plus Cesium.
Lithium Carbide	A mixture of lithium carbide and phosphorus burns if the mixture is warm.
	Mellor **5:** 848 (1946-1947).
Lithium Silicide	Lithium silicide attacks phosphorus, selenium or tellurium with incandescence.
	Mellor **6:** 169 (1946-1947).
Magnesium Bromate	See PHOSPHORUS plus Bromates.
Magnesium Chlorate	See PHOSPHORUS plus Bromates.
Magnesium Iodate	See PHOSPHORUS plus Bromates.
Magnesium Perchlorate	A student was injured by an explosion when he attempted to mix these two chemicals in the laboratory.
	1965 Sum. Serious Acc. (1966).
Manganese	See MANGANESE plus Phosphorus.
Mercuric Oxide	A mixture of mercuric oxide and phosphorus explodes when struck with a hammer and when boiled with water and phosphorus.
	Mellor **4:** 778 (1946-1947).
Mercurous Nitrate	A mixture of mercurous nitrate and phosphorus explodes violently when struck with a hammer.

	Mellor **4:** 987 (1946-1947).
Neodymium	See NEODYMIUM plus Phosphorus.
Nickel	See COPPER plus Phosphorus.
Nitrates	A mixture of the two may cause an explosion.
	Pieters, p. 30 (1957).
Nitric Acid	Phosphorus ignites in the vapor of nitric acid and burns with an intense white light.
	Berrere & Moutet, *Symposium Comb.* (**Fifth**)**:** 170-81 (1954).
Nitrogen Bromide	Nitrogen bromide explodes violently in contact with phosphorus.
	Mellor **8, Supp. I, Part 2:** 707 (1964).
Nitrogen Dioxide	See MAGNESIUM plus Nitrogen Dioxide.
Nitrogen Tribromide	See ARSENIC plus Nitrogen Tribromide.
Nitrogen Trichloride	See NITROGEN TRICHLORIDE plus Ammonia.
Nitrosyl Fluoride	See BORON plus Nitrosyl Fluoride.
Nitryl Fluoride	Red phosphorus and nitryl fluoride react at room temperature.
	Mellor **8, Supp. 3:** 264 (1971).
Oxygen	Phosphorus and oxygen or iodine undergo a vigorous reaction at room temperature.
	Mellor **8, Supp. 3:** 228 (1971).
Performic Acid	Red phosphorus is violently oxidized by performic acid.
	Grignard **11:** 179 (1935-1954).
	Berichte **48:** 1139 (1915).
Platinum	See COPPER plus Phosphorus.
Potassium	See PHOSPHORUS plus Cesium.
Potassium Bromate	See PHOSPHORUS plus Bromates.
Potassium Chlorate	If a drop of solution of phosphorus in carbon disulfide is placed on powdered potassium chlorate, an explosion

	occurs as the solvent evaporates.
	R. Bottger, *Repert. Pharm.* **24:** 725 (1875).
	Ellern, p. 50 (1968).
	See also PHOSPHORUS plus Bromates.
Potassium Hydroxide	When phosphorus is boiled with a solution of sodium or potassium hydroxide, phosphine gas is evolved which is spontaneously flammable.
	Mellor **8:** 804-5 (1946-1947).
	See PHOSPHORUS plus Alkaline Hydroxides.
Potassium Iodate	If red or white phosphorus is mixed with potassium iodate and moistened with a few drops of water, the mixture reacts violently, sometimes explosively.
	J. Am. Chem. Soc. **49:** 9 (1927).
	See also PHOSPHORUS plus Bromates.
Potassium Nitride	Potassium nitride unites with sulfur or phosphorus when heated, forming a highly flammable mixture.
	Mellor **8:** 99 (1946-1947).
Potassium	Crystals of potassium permanganate explode
Permanganate	vigorously when ground with phosphorus.
	Mellor **12:** 322 (1946-1947).
Potassium Peroxide	A mixture of phosphorus and potassium peroxide causes fire or explosion.
	Mellor **2:** 490-93 (1946-1947). *Von Schwartz*, p. 328 (1918).
Rubidium	See PHOSPHORUS plus Cesium.
Rubidium Acetylene	Rubidium acetylene carbide ignites in contact
Carbide	with molten sulfur. It becomes incandescent when warmed in contact with phosphorus.
	Mellor **5:** 849 (1946-1947).
Selenium Monochloride	White phosphorus mixed with selenium monochloride explodes.

	Mellor **8, Supp. 3:** 264 (1971).
Selenium Oxychloride	Red phosphorus reacts in the cold with selenium oxychloride evolving light and heat; white phosphorus reacts explosively.
	Mellor **10:** 906 (1946-1947).
Selenium Oxyfluoride	This mixture ignites spontaneously.
	Mellor **8, Supp. 3:** 264 (1971).
Selenium Tetrafluoride	This mixture produces a violent reaction.
	Mellor **8, Supp. 3:** 264 (1971).
Silver Nitrate	A mixture of silver nitrate and phosphorus explodes violently when struck with a hammer.
	Mellor **3:** 470 (1946-1947).
Silver Oxide	When amorphous phosphorus is ground with silver oxide, the mixture ignites.
	Mellor **3:** 377 (1946-1947).
Sodium	See PHOSPHORUS plus Cesium.
Sodium Bromate	See PHOSPHORUS plus Bromates.
Sodium Carbide	Sodium carbide burns vigorously in phosphorus vapor.
	Mellor **5:** 848-50 (1946-1947).
Sodium Chlorate	See PHOSPHORUS plus Bromates.
Sodium Chlorite	Red phosphorus and sodium chlorite react in aqueous suspension in a strongly exothermic manner. The reaction can have a sudden, almost explosive stage.
	Mellor **8, Supp. 3:** 645 (1971).
Sodium Hydroxide	See PHOSPHORUS plus Potassium Hydroxide and PHOSPHORUS plus Alkaline Hydroxides.
Sodium Iodate	See PHOSPHORUS plus Bromates.
Sodium Peroxide	Phosphorus and sodium peroxide react with flame or explosion.
	Mellor **2:** 490-93 (1946-1947). *Von Schwartz,* p. 328 (1918).

Sulfur	When a mixture of sulfur and yellow phosphorus is warmed, the two elements unite in all proportions with vivid combustion and powerful explosions.
	Ann. Chim. et Phys. (1) **4:** 1. *Ann. Chim. et Phys.* (2) **67:** 332. *Comp. Rend.* **96:** 1499, 1771. R. Bottger, *J. Prakt. Chem.* (1) **12:** 357 (1837).
	See PHOSPHORUS plus Cesium.
Sulfur Trioxide	Yellow phosphorus ignites after exposure to the vapor of sulfur trioxide. A piece of phosphorus dropped into liquid sulfur trioxide reduces the latter with violence. When the pieces of phosphorus are large, the heat raises the temperature of the phosphorus sufficiently to cause ignition.
	F. C. Vogel, *Schweigger's Jour.* **4:** 121 (1812).
Sulfuric Acid	Yellow phosphorus ignites when placed in boiling concentrated sulfuric acid.
	A. Oppenheim, *Bull. Soc. Chim.* (2) **1:** 163 (1864).
Thorium	When thorium is heated with phosphorus, they unite with incandescence.
	J. J. Berzelius, *Svenska Akad.*, p. 1 (1829).
Vanadium	This mixture produces an explosive reaction
Oxytrichloride	below 100¡ C with more than small amounts.
	Mellor **8, Supp. 3:** 264 (1971).
Zinc Bromate	See PHOSPHORUS plus Bromates.
Zinc Chlorate	See PHOSPHORUS plus Bromates.
Zinc Iodate	See PHOSPHORUS plus Bromates.
Zirconium	Phosphorus and zirconium react with incandescence when heated in a vacuum.
	Mellor **7:** 114-16 (1946-1947).

PHOSPHORUS CYANIDE P_3CN

Air	This very reactive cyanide ignites in air when touched with

	a warm rod.
	Mellor **8, Supp. 3:** 583 (1971).
Water	Phosphorus cyanide reacts violently with water.
	Mellor **8, Supp. 3:** 583 (1971).

PHOSPHORUS HEXAOXYTETRASULFIDE $P_4O_6S_4$

Water	This sulfide decomposes rapidly in moist air.
	Mellor **8, Supp. 3:** 437 (1971).

PHOSPHORUS ISOCYANATE P_3OCN

Acetaldehyde	Phosphorus isocyanate and acetaldehyde, acetic acid, silver nitrate, or sulfuric acid react violently.
	Mellor **8, Supp. 3:** 585 (1971).
Acetic Acid	See PHOSPHORUS ISOCYANATE plus Acetaldehyde.
Chlorine	See CHLORINE plus Phosphorus Isocyanate.
Silver Nitrate	See PHOSPHORUS ISOCYANATE plus Acetaldehyde.
Sulfuric Acid	See PHOSPHORUS ISOCYANATE plus Acetaldehyde.
Water	The hydrolysis of phosphorus isocyanate is rapid.
	Mellor **8, Supp. 3:** 585 (1971).

PHOSPHORUS OXIDE P_2O_3

(See PHOSPHORUS TRIOXIDE)

PHOSPHORUS PENTACHLORIDE PCl_5

Chlorine Trioxide	See CHLORINE TRIOXIDE plus Phosphorus Pentachloride.
Fluorine	See FLUORINE plus Phosphorus Pentachloride.

Hydroxylamine	See PHOSPHORUS TRICHLORIDE plus Hydroxylamine.
Magnesium Oxide	These materials react with brilliant incandescence.
	Mellor **8:** 1016 (1946-1947).
Phosphorus Trioxide	See PHOSPHORUS TRIOXIDE plus Phosphorus Pentachloride.
Potassium	See POTASSIUM plus Boron Tribromide.
Sodium	See SODIUM plus Phosphorus Pentachloride.
	See SODIUM plus Cobaltous Bromide.
Water	Phosphorus pentachloride reacts violently with water.
	Oldbury Chemicals, p. 9.

PHOSPHORUS PENTASULFIDE P_2S_5

Water	Phosphorus pentasulfide heats spontaneously, and may ignite, in the presence of moisture.
	Haz. Chem. Data (1969).

PHOSPHORUS PENTOXIDE P_2O_5

Ammonia	Reaction of phosphorus pentoxide and ammonia is rapid, contrary to older reports.
	Mellor **8, Supp. 1:** 331 (1964).
	This is a vigorous reaction.
	Mellor **8, Supp. 3:** 403 (1971).
Calcium Oxide	See CALCIUM OXIDE plus Phosphorus Pentoxide.
Chlorine Trifluoride	See CHLORINE TRIFLUORIDE plus Arsenic Trioxide.
Hydrogen Fluoride	Phosphorus pentoxide unites with hydrogen fluoride vigorously, even at 19.5¡ C.
	G. Gore, *Proc. Roy. Soc.* **17:** 256 (1869).
Oxygen Difluoride	See OXYGEN DIFLUORIDE plus Aluminum Chloride.

Perchloric Acid	See PERCHLORIC ACID plus Sulfuric Acid.
Perchloric Acid and Chloroform	A violent explosion occurs if a solution of perchloric acid in chloroform is poured on phosphorus pentoxide.
	J. Am. Chem. Soc. **23:** 444 (1901).
Potassium	See POTASSIUM plus Phosphorus Pentoxide.
Propargyl Alcohol	Addition of phosphorus pentoxide to propargyl alcohol caused the alcohol to burst into flame.
	Monroe (1966).
Sodium	See POTASSIUM plus Phosphorus Pentoxide.
Sodium Carbonate	See SODIUM CARBONATE plus Phosphorus Pentoxide.
Sodium Hydroxide	See CALCIUM OXIDE plus Phosphorus Pentoxide.
Water	Phosphorus pentoxide reacts violently with water.
	Oldbury Chemicals, p. 9.
Water and Organic Matter	Mixed with water and combustible material, phosphoric anhydride produces great heat and often ignites the combustible material.
	Chem. Safety Data Sheet **SD-23:** 3 (1948).

PHOSPHORUS TETRATRIIODIDE

(See TETRAPHOSPHORUS TRIIODIDE)

PHOSPHORUS TETRAOXYTRISULFIDE $P_4O_4S_3$

Water	The sulfide ignites if moistened with a little water.
	Mellor **8, Supp. 3:** 437 (1971).

PHOSPHORUS TETRATRISELENIDE

(See TETRAPHOSPHORUS TRISELENIDE)

PHOSPHORUS TRIBROMIDE PBr_3

Potassium	See POTASSIUM plus Boron Tribromide.
Ruthenium Tetroxide	See RUTHENIUM TETROXIDE plus Phosphorus Tribromide.
Sodium	See SODIUM plus Phosphorus Tribromide.
	See SODIUM plus Cobaltous Bromide.

PHOSPHORUS TRICHLORIDE PCl_3

Acetic Acid	Several laboratory explosions have occurred using this reaction to form acetyl chloride. Poor heat control probably caused formation of phosphine.
	J. Am. Chem. Soc. **60:** 488 (1938).
Aluminum	See ALUMINUM plus Phosphorus Trichloride.
Chromyl Chloride	See CHROMYL CHLORIDE plus Phosphorus Trichloride.
Diallyl Phosphite and	See DIALLYL PHOSPHITE plus Allyl
Allyl Alcohol	Alcohol and Phosphorus Trichloride.
Dimethyl Sulfoxide	See DIMETHYL SULFOXIDE plus Acyl Halides.
Fluorine	See FLUORINE plus Phosphorus Trichloride.
Hydroxylamine	Ignition occurs when hydroxylamine is mixed with phosphorus trichloride or phosphorus pentachloride.
	Mellor **8:** 290 (1946-1947).
Iodine Monochloride	See IODINE MONOCHLORIDE plus Phosphorus Trichloride.
Lead Dioxide	See LEAD DIOXIDE plus Phosphorus Trichloride.
Nitric Acid	An explosion occurs when phosphorus trichloride is brought in contact with nitric or nitrous acid.
	Comp. Rend. **28:** 86.
Nitrous Acid	See PHOSPHORUS TRICHLORIDE plus Nitric Acid.
Organic Matter	See PHOSPHORUS OXYCHLORIDE plus Organic

	Matter.
Potassium	See POTASSIUM plus Phosphorus Trichloride.
Sodium	See SODIUM plus Phosphorus Trichloride.
Water	The reaction between water and phosphorus trichloride is extremely violent. The reaction may be due to the formation of phosphine or elemental phosphorus. The possible presence of hydrogen may intensify these flashes of fire.
	Chem. Safety Data Sheet **SD-27** (1948).

PHOSPHORUS TRIFLUORIDE PF_3

Diborane	The reaction product of this combination, borane-phosphorus trifluoride compound, is spontaneously flammable in air.
	Mellor **8, Supp. 3:** 442 (1971).
Fluorine	See FLUORINE plus Phosphorus Trifluo ride.
Oxygen	See OXYGEN plus Phosphorus Trifluoride.

PHOSPHORUS TRIFLUORIDE-BORANE COMPOUND H_3BPF_3

(self-reactive)	See PHOSPHOROUS TRIFLUORIDE plus Diborane.

PHOSPHORUS TRIOXIDE P_4O_6

Air	Melted phosphorus trioxide readily ignites in air. When thrown into oxygen (heated to 50-60¡ C.), it instantly ignites with a flame of almost blinding brilliance.
	W.E. Downey, *J. Chem. Soc.* **125:** 347 (1924).
Ammonia	If ammonia is passed over phosphorus trioxide, which has been melted by the warmth of the hand, a somewhat violent reaction occurs and the mass ignites. The reaction is slow if the materials are kept cold.
	Thorpe and Tutton, *J. Chem. Soc.* **59:** 1019 (1891). *Mellor*

	8: 898 (1946-1947).
Arsenic Trifluoride	See ARSENIC TRIFLUORIDE plus Phosphorus Trioxide.
Bromine	See BROMINE plus Phosphorus Trioxide. See also CHLORINE plus Phosphorus Oxide.
Chlorine	See BROMINE plus Phosphorus Trioxide. See also CHLORINE plus Phosphorus Oxide.
Dimethyl Formamide	See DIMETHYL FORMAMIDE plus Phosphorus Trioxide.
Dimethyl Sulfoxide	See DIMETHYL FORMAMIDE plus Phosphorus Trioxide.
Dimethyl Sulfite	See DIMETHYL FORMAMIDE plus Phosphorus Trioxide.
Methanol	See DIMETHYL FORMAMIDE plus Phosphorus Trioxide.
Oxygen	See PHOSPHORUS TRIOXIDE plus Air.
Phosphorus Pentachloride	The reaction between phosphorus trioxide and phosphorus pentachloride is violent at ordinary temperatures.
	Thorpe and Tutton, *J. Chem. Soc.* **57:** 545 (1890).
Sulfur	See SULFUR plus Phosphorus Trioxide.
Sulfur Monochloride	Sulfur monochloride acts with great violence on phosphorus trioxide.
	Thorpe and Tutton, *J. Chem. Soc.* **59:** 1019 (1891). *Mellor* **8:** 898 (1946-1947).
Water	With quantities of phosphorus trioxide exceeding a couple of grams, hot water produces a violent explosion.
	Thorpe and Tutton, *J. Chem. Soc.* **59:** 1019 (1891). *Mellor* **8:** 897 (1946-1947).

PHOSPHORYL BROMODIFLUORIDE $POBrF_2$

Water	See PHOSPHORYL FLUORIDE plus Water.

PHOSPHORYL CHLORIDE $POCl_3$

Boron Triiodide	Phosphoryl chloride and boron triiodide react vigorously.
	Mellor **5:** 136 (1946-1947).
2,5-Dimethylpyrrole and Dimethyl Formamide	See 2,5-DIMETHYLPYRROLE plus Phosphorus Oxychloride and Dimethyl Formamide.
Dimethyl Sulfoxide	See DIMETHYL SULFOXIDE plus Acyl Halides.
Organic Matter	Fibrous organic matter (wood, etc.), when dry, readily absorbs phosphorus oxychloride. When thus absorbed, it may constitute a fire hazard. Both phosphorus oxychloride and phosphorus trichloride are strongly corrosive and may set fire to combustible material.
	Chem. Safety Data Sheet **SD-26** (1948). B. L. Heustis, *Safety Eng.* **54:** 95 (1927).
Sodium	See SODIUM plus Phosphoryl Chloride.
Water	When water reacts with phosphorus oxychloride, there is little warning; first a little bubbling and then a rapid acceleration and pressure increase. Small quantities of phosphorus oxychloride were emptied into a scrap nickel drum containing about 28 pounds of water. After a delay of 15 to 30 minutes, the drum exploded.
	MCA Task Group, POCl (Jan. 19, 1967).
	MCA Case History **1274** (1967). *MCA Case History* **793** (1962). *Chem. Safety Data Sheet* **SD-26** (1948).

PHOSPHORYL CHLORODIFLUORIDE $POClF_2$

Water	See PHOSPHORYL FLUORIDE plus Water.

PHOSPHORYL DIBROMOFLUORIDE $POBr_2F$

Water	See PHOSPHORYL FLUORIDE plus Water.

PHOSPHORYL DICHLOROFLUORIDE $POCl_2F$

Water | See PHOSPHORYL FLUORIDE plus Water.

PHOSPHORYL FLUORIDE POF_3

Water | The hydrolysis of phosphoryl fluoride and the halofluorides (phosphoryl chlorodifluoride, phosphoryl dichlorofluoride, phosphoryl bromodifluoride, and phosphoryl dibromofluoride) is a vigorous reaction.

Mellor **8, Supp. 3:** 458 (1971).

PHTHALIC ACID $HOCOC_6H_4COOH$

Nitric Acid | See PHTHALIC ANHYDRIDE plus Nitric Acid.

PHTHALIC ANHYDRIDE

Nitric Acid | The exothermic nitration of phthalic acid or phthalic anhydride by a fuming nitric acid — sulfuric acid mixture may give mixtures of the potentially explosive phthaloyl nitrates or nitrites or their nitro derivatives. Formation of these compounds may be avoided if the nitrating mixture is extensively diluted with sulfuric acid and if a small (1.5 mole equivalent) of nitric acid is present.

Chem. & Ind. **20:** 790 (1972). *Chem. & Ind.* **17:** 664 (1972).

PICRATES

(See also specific picrates as primary entries and under other reactants.)

Sulfuric Acid	See SULFURIC ACID plus Carbides.

PICRIC ACID $(NO_2)_3C_6H_2OH$

Ammonia	Ammonia and metals with picric acid give results similar to bases.
	Military Explosives.
	See also PICRIC ACID plus Bases.
Bases	Picric acid and bases form explosive salts. The salts with heavy metals (e.g., lead) are very sensitive to primary explosives.
	Davis, pp. 164-68 (1943).
Concrete	Contact between picric acid and concrete floors leads to the formation of more explosion-sensitive salts, such as calcium picrate.
	Urbanski **1:** 518 (1964).
Metals	See PICRIC ACID plus Bases.

PLATINUM Pt

Bromine Trifluoride	Platinum is attacked by bromine trifluoride at
and Potassium	280¡ C in presence of potassium fluoride.
Fluoride	*Mellor* **2, Supp. 1:** 164 (1956).
Hydrogen and Oxygen	See HYDROGEN plus Oxygen and Platinum.
Hydrogen Peroxide	A little platinum black dropped into a hydrogen peroxide solution may cause an explosion.
	Mellor **1:** 936 (1946-1947).
Lithium	See LITHIUM plus Platinum.
Oxygen Difluoride	See IRIDIUM plus Oxygen Difluoride.
Permonosulfuric Acid	The decomposition of 92 per cent permonosulfuric acid is explosive in the presence of smooth or finely divided platinum, manganese dioxide or silver.

Mellor **10:** 483 (1946-1947).

Phosphorus	See COPPER plus Phosphorus.

PLATINIC BROMIDE $PtBr_4$

Bromine Trifluoride	See BROMINE TRIFLUORIDE plus Platinic Bromide.

PLATINIC CHLORIDE $PtCl_4$

Bromine Trifluoride	See BROMINE TRIFLUORIDE plus Platinic Bromide.

PLATINOUS HYPOPHOSPHITE $Pt(PH_2O_2)_2$

(self-reactive)	Platinous hypophosphite liberates spontaneously flammable phosphine above 130¡ C. *Mellor* **8:** 890 (1946-1947).

PLATINUM-AMMINE NITRATES

(self-reactive)	Platinum-amine nitrates may be impact-sensitive. $Pt(NH_3)_2NO_3$ and $Pt(NH_3)_4(OH)_2$ $(NO_3)_2$ detonate when heated. *Mellor* **16:** 412 (1946-1947).

PLATINUM-AMMINE PERCHLORATES

(self-reactive)	Platinum-ammine perchlorates may be impact-sensitive. *Mellor* **16:** 412 (1946-1947).

PLUTONIUM Pu

Air	See PLUTONIUM plus Water.
Carbon Tetrachloride	Plutonium metal chips degreased in carbon tetrachloride and allowed to drain for five minutes ignited spontaneously. When the burning chips were inadvertently

	dropped into the carbon tetrachloride container, an explosion resulted.
	Ser. Acc. Series No. **246** (1965).
Water	Pyrophoric products form on plutonium and particularly on certain alloys if they are stored for long periods in closed containers. When a container is opened, spontaneous ignition may occur. Plutonium corrosion is accelerated by atmospheric moisture and a hydride is formed. This corrosion also occurs in moist inert gases. The corrosion products are frequently pyrophoric.
	Wick, pp. 148-152, 331-332, 338 (1967).

PLUTONIUM HYDRIDE PuH_2

Air	Plutonium hydride in some forms is spontaneously flammable in air. See also PLUTONIUM plus Carbon Tetrachloride and PLUTONIUM plus Water.
	Chem. Eng. News **36** (8): 64 (1958).

POLYAMIDE

Fluorine	See FLUORINE plus Solid Nonmetals and Oxygen.

POLYCHLORINATED BIPHENYL

Chlorine	See CHLORINE plus Polychlorinated Biphenyl.

POLYCHLOROPRENE

(See NEOPRENE)

POLYDIMETHYLSILOXANE $[-Si(CH_3)_2O-]_x$

Chlorine	See CHLORINE plus Polypropylene.

POLYETHYLENE

Fluorine	See FLUORINE plus Solid Nonmetals and Oxygen.

POLYISOBUTYLENE $[CH_2{=}C(CH_3)_2]_x$

Silver Peroxide	See SILVER PEROXIDE plus Polyisobutylene.

POLYMETHYLMETHACRYLATE

(See METHYL METHACRYLATE POLYMER)

POLYPHOSPHORYL CHLORIDES

Water	These polymers hydrolyze violently. *Mellor* **8, Supp. 3:** 507 (1971).

POLYPROPYLENE $(CH_2{=}CHCH_3)_x$

Chlorine	See CHLORINE plus Polypropylene.
Potassium Permanganate	See POTASSIUM PERMANGANATE plus Polypropylene.

POLYSULFIDE POLYMERS

Calcium Peroxide	See CALCIUM PEROXIDE plus Polysulfide Polymers.

POLYTETRAFLUOROETHYLENE

(See TETRAFLUOROETHYLENE POLYMER)

POLYURETHANE

Fluorine and Oxygen	See FLUORINE plus Solid Nonmetals and Oxygen.

POLYVINYLCHLORIDE ACETATE

(See VINYL ACETATE-CHLORIDE COPOLYMER)

POTASSIOPHOSPHINE KPH_2

(See POTASSIUM DIHYDROPHOSPHIDE)

POTASSIUM K

(See IODINE plus Lithium)

Acetylene	Molten potassium ignites in acetylene.
	M. Berthelot, *Bull. Soc. Chim.* (2) **5:** 188 (1866).
Air	The oxidation of potassium may proceed so rapidly that the heat generated melts and ignites the metal. This is particularly the case where pressure is applied at ordinary temperatures; the metal then liquefies where the pressure is applied, and takes fire.
	Sidgwick **1** (1950).
	Potassium burns in moist air at room temperature.
	Mellor **2:** 468 (1946-1947).
	Potassium is spontaneously flammable in air at room temperature if the surface of the metal is clean.
	Mellor **2:** 468 (1946-1947).
	The higher oxides of potassium, formed in air, react explosively with pure potassium, sodium, sodium-potassium alloys, and organic matter.
	Mellor **2, Supp. 3:** 1559 (1963).
Aluminum Bromide	A mixture of potassium and any of the following metallic halides produces a strong explosion on impact: aluminum bromide, aluminum chloride, aluminum fluoride, ammonium chlorocuprate, antimony tribromide, antimony trichloride, antimony triiodide, arsenic trichloride, arsenic triiodide, bismuth tribromide, bismuth trichloride, bismuth triiodide, cadmium bromide, cadmium chloride, cadmium iodide, chromium tetrachloride, cupric bromide, cupric

	chloride, cuprous bromide, cuprous chloride, cuprous iodide, manganous chloride, mercuric bromide, mercuric chloride, mercuric fluoride, mercuric iodide, mercurous chloride, nickel bromide, nickel chloride, nickel iodide, silicon tetrachloride, silver fluoride, stannic chloride, stannic iodide (with sulfur), stannous chloride, sulfur dibromide, thallous bromide, vanadium pentachloride, zinc bromide, zinc chloride, and zinc iodide.
	Mellor **2, Supp. 3:** 1571 (1963).
Aluminum Chloride	See POTASSIUM plus Aluminum Bromide.
Aluminum Fluoride	See POTASSIUM plus Aluminum Bromide.
Ammonium Chlorocuprate	See POTASSIUM plus Aluminum Bromide.
Ammonium Bromide	A mixture of potassium and any of the following compounds produces a weak explosion on impact: ammonium bromide, ammonium iodide, cadmium fluoride, chromium trifluoride, manganous bromide, manganous iodide, nickel fluoride, potassium chlorocuprate, silver chloride, silver iodide, strontium iodide, thallous chloride, and zinc fluoride.
	Mellor **2, Supp. 3:** 1571 (1963).
Ammonium Iodide	See POTASSIUM plus Ammonium Bromide.
Ammonium Sulfate and Ammonium Nitrate	A mixture of ammonium sulfate and ammonium nitrate can easily be exploded by potassium or sodium-potassium alloy.
	H. Staudinger, *Z. Elektrokem.* **31:** 549-52 (1925).
Antimony Tribromide	See POTASSIUM plus Aluminum Bromide.
Antimony Trichloride	See POTASSIUM plus Aluminum Bromide.
Antimony Triiodide	See POTASSIUM plus Aluminum Bromide.
Arsenic Trichloride	See POTASSIUM plus Aluminum Bromide.
Arsenic Triiodide	See POTASSIUM plus Aluminum Bromide.
Arsine and Ammonia	Potassium and arsine react vigorously in liquid ammonia at minus 78¡ C. The product reacts vigorously with air.

	Mellor **2, Supp. 3:** 1579 (1963).
Bismuth Tribromide	See POTASSIUM plus Aluminum Bromide.
Bismuth Trichloride	See POTASSIUM plus Aluminum Bromide.
Bismuth Triiodide	See POTASSIUM plus Aluminum Bromide.
Bismuth Trioxide	Potassium reduces heated bismuth trioxide to the metal and the reaction is accompanied by incandescence. Similar results are obtained with sodium.
	Mellor **9:** 649 (1946-1947).
Boric Acid	A mixture of potassium and any of the following compounds may explode on impact: boric acid, copper oxychloride, lead oxychloride, lead peroxide, lead sulfate, silver iodate, sodium iodate, and vanadium oxychloride.
	Mellor **2, Supp. 3:** 1571 (1963).
Boron Tribromide	A mixture of potassium and any of the following halide compounds produces a very violent explosion on impact: boron tribromide, carbon tetrachloride, cobaltous bromide, cobaltous chloride, ferric bromide, ferric chloride, ferrous bromide, ferrous chloride, ferrous iodide, phosphorus pentachloride, phosphorus tribromide and sulfur dichloride.
	Mellor **2, Supp. 3:** 1571 (1963).
Bromine	See BROMINE plus Potassium.
Cadmium Bromide	See POTASSIUM plus Aluminum Bromide.
Cadmium Chloride	See POTASSIUM plus Aluminum Bromide.
Cadmium Fluoride	See POTASSIUM plus Ammonium Bromide.
Cadmium Iodide	See POTASSIUM plus Aluminum Bromide.
Carbon	See POTASSIUM plus Graphite and Potassium Superoxide.
Carbon Dioxide	Mixture of solid forms of potassium and carbon dioxide (as dry ice) explodes when subjected to shock.
	Mellor **2, Supp. 3:** 1568 (1963).
Carbon Disulfide	Heated potassium ignites in the vapor of carbon disulfide. Potassium and carbon disulfide can be exploded by pressure or friction.

	Von Schwartz, p. 327. *Ann. Phys.* **6:** 444 (1826).
Carbon Monoxide and Oxygen	The reaction of potassium and carbon monoxide forms an explosive carbonyl compound, potassium carbonyl, which reacts violently with oxygen.
	Mellor **2, Supp. 3:** 1567 (1963).
	See also SODIUM CARBONYL plus Air.
Carbon Tetrachloride	Potassium and its alloys form explosive mixtures with carbon tetrachloride.
	H.N. Gilbert, *Chem. Eng. News* **26:** 2604 (1948).
	See POTASSIUM plus Boron Tribromide.
Charcoal	Both charcoal and graphite react vigorously with liquid potassium.
	Mellor **2, Supp. 3:** 1566 (1963).
Chlorinated Hydrocarbons	Potassium and its alloys form explosive mixtures with chlorinated hydrocarbons.
	H. N. Gilbert, *Chem. Eng. News* **26:** 2604 (1948).
Chlorine	Potassium burns spontaneously in dry chlorine.
	Mellor **2:** 469 (1946-1947).
Chlorine Monoxide	Mere contact of chlorine monoxide gas with paper, caoutchouc (India rubber), turpentine, sulfur, potassium, phosphorus, charcoal, arsenic, or antimony is attended by a violent explosion.
	Mellor **2:** 241 (1946-1947).
Chlorine Trifluoride	See ANTIMONY plus Chlorine Trifluoride.
Chloroform	The alkali metals react explosively with chloroform, dichloromethane, and methyl chloride.
	See LITHIUM plus Chloroform.
	Z. Electrochem. **31:** 549 (1925).
Chromium Tetrachloride	See POTASSIUM plus Aluminum Bromide.

Chromium Trifluoride	See POTASSIUM plus Ammonium Bromide.
Chromium Trioxide	Sodium or potassium reacts with chromium trioxide with incandescence.
	Mellor **11:** 237 (1946-1947).
Cobaltous Bromide	See POTASSIUM plus Boron Tribromide.
Cobaltous Chloride	See POTASSIUM plus Boron Tribromide.
Copper Oxychloride	See POTASSIUM plus Boric Acid.
Cupric Bromide	See POTASSIUM plus Aluminum Bromide.
Cupric Chloride	See POTASSIUM plus Aluminum Bromide.
Cupric Oxide	Cupric oxide is reduced to metallic copper when heated with potassium at a temperature below its melting point. The reaction proceeds with vivid incandescence.
	Berichte **24.**
Cuprous Bromide	See POTASSIUM plus Aluminum Bromide.
Cuprous Chloride	See POTASSIUM plus Aluminum Bromide.
Cuprous Iodide	See POTASSIUM plus Aluminum Bromide.
Dichloromethane	See POTASSIUM plus Chloroform.
Ethylene Oxide	Ethylene oxide is dangerously reactive with metallic potassium.
	Chem. Safety Data Sheet **SD-38:** 11 (1951).
	See ETHYLENE OXIDE plus Acids and Bases.
Ferric Bromide	See POTASSIUM plus Boron Tribromide.
Ferric Chloride	See POTASSIUM plus Boron Tribromide.
Ferrous Bromide	See POTASSIUM plus Boron Tribromide.
Ferrous Chloride	See POTASSIUM plus Boron Tribromide.
Ferrous Iodide	See POTASSIUM plus Boron Tribromide.
Fluorine	Potassium burns spontaneously in dry fluorine.
	Mellor **2:** 469 (1946-1947).
Graphite	See POTASSIUM plus Charcoal.

Graphite and Air	See POTASSIUM plus Graphite and Potassium Superoxide.
Graphite and Potassium Superoxide	Potassium superoxide forms on the surface of either solid or molten potassium metal. Attempts to extinguish burning potassium with powdered graphite have resulted in violent explosions.
	Chem. Abst. **63** (1): 424 (July 5, 1965).
	Mellor **2, Supp. 3:** 1566 (1963).
Hydrogen Iodide	Potassium burns momentarily in hydrogen iodide; the flame then goes out.
	M. Ribalkin, *Bull. Acad. St. Petersbourg* (2) **1:** 279 (1889).
	A very violent explosion results when a mixture of potassium and hydrogen iodide is struck by a hammer.
	Mellor **2, Supp. 3:** 1563 (1963).
Hydrogen Peroxide	See LEAD DIOXIDE plus Hydrogen Peroxide.
Iodine	See IODINE plus Potassium.
	See IODINE plus Lithium.
Iodine Monobromide	Potassium in contact with molten iodine monobromide creates a strong explosion.
	Mellor **2, Supp. 3:** 1563 (1963).
Iodine Monochloride	Potassium explodes in contact with iodine monochloride, but the reaction of sodium is very slow.
	A. Vogel, *Kastner's Arch.* **10:** 119 (1827).
	Berichte **31:** 892.
	Mellor, **2, Supp. 1:** 501 (1956).
	Mellor, **2, Supp. 3:** 1563 (1963).
Iodine Pentafluoride	A mixture of iodine pentafluoride and potassium or sodium (molten) will explode.
	Mellor **2:** 114 (1946-1947).
Lead Oxychloride	See POTASSIUM plus Boric Acid.

Lead Peroxide	See POTASSIUM plus Boric Acid.
Lead Sulfate	See POTASSIUM plus Boric Acid.
Maleic Anhydride	See ALKALI METALS plus Maleic Anhydride.
Manganous Bromide	See POTASSIUM plus Ammonium Bromide.
Manganous Chloride	See POTASSIUM plus Aluminum Bromide.
Manganous Iodide	See POTASSIUM plus Ammonium Bromide.
Mercuric Bromide	See POTASSIUM plus Aluminum Bromide.
Mercuric Chloride	See POTASSIUM plus Aluminum Bromide.
Mercuric Fluoride	See POTASSIUM plus Aluminum Bromide.
Mercuric Iodide	See POTASSIUM plus Aluminum Bromide.
Mercurous Chloride	See POTASSIUM plus Aluminum Bromide.
Mercurous Oxide	Molten sodium or potassium decomposes mercurous oxide with slight explosion.
	J. B. Senderens, *Bull. Soc. Chim.* (3)**6:** 802 (1891).
Methyl Chloride	See POTASSIUM plus Chloroform.
Molybdenum Trioxide	Molybdenum trioxide is reduced by either potassium or sodium with incandescence.
	Z. Anorg. Chemie **190:** 270.
Nickel Bromide	See POTASSIUM plus Aluminum Bromide.
Nickel Chloride	See POTASSIUM plus Aluminum Bromide.
Nickel Fluoride	See POTASSIUM plus Ammonium Bromide.
Nickel Iodide	See POTASSIUM plus Aluminum Bromide.
Nitrogen Dioxide	Potassium ignites in nitrogen dioxide at ordinary temperatures.
	Mellor **8:** 544 (1946-1947).
	See also MANGANESE plus Nitrogen Dioxide.
Nitryl Fluoride	Heated potassium metal burns with a lilac flame in vapor of nitryl fluoride.
	Mellor **2, Supp. 3:** 1566 (1963).

Peroxides	See ANTIMONY plus Sodium Peroxide.
Phosgene	Mixture of potassium and phosgene explodes when subjected to shock.
	Mellor **2, Supp. 3:** 1568 (1963).
Phosphine and	Potassium and phosphine react in liquid
Ammonia	ammonia to form potassium dihydrophosphide, a spontaneously flammable solid.
	Mellor **8, Supp. 3:** 283 (1971).
Phosphorus	See PHOSPHORUS plus Cesium.
Phosphorus	See POTASSIUM plus Boron Tribromide.
Pentachloride	
Phosphorus Pentoxide	When phosphorus pentoxide is warmed with potassium or sodium, the mixture becomes incandescent.
	H. Davy, *Phil. Trans. Roy. Soc. London* **102:** 405 (1812).
Phosphorus Tribromide	See POTASSIUM plus Boron Tribromide.
Phosphorus	Potassium burns vigorously in the vapor of
Trichloride	phosphorus trichloride.
	H. Davy, *Phil. Trans. Roy. Soc. London* **100:** 231 (1810); **101:** 1 (1811).
Potassium	See POTASSIUM plus Ammonium Bromide.
Chlorocuprate	
Potassium Oxides	See POTASSIUM plus Air.
Potassium Ozonide	Potassium in contact with the following oxides causes an explosive reaction: potassium ozonide, potassium peroxide, potassium superoxide.
	Mellor **2, Supp. 3:** 1577 (1963).
Potassium Peroxide	Potassium peroxide oxidizes many metals with incandescence; e.g., potassium, arsenic, antimony, tin, zinc, and copper.
	Mellor **2:** 490-3 (1946-1947).

	See POTASSIUM plus Potassium Ozonide.
Potassium Superoxide	Potassium metal sometimes forms an orange-yellow coating of tetroxide, even under mineral oil. A 2 cc. lump of such potassium, while being sliced with a stainless steel knife, suddenly exploded and burned.
	Short (1966). *Health & Safety Info.* **257** (March 31, 1967).
	Potassium superoxide scale being chipped off metallic potassium was driven into the underlying metal, and caused a violent explosion.
	H. N. Gilbert, *Chem. Eng. News* **26:** 2604 (1948).
	See POTASSIUM plus Potassium Ozonide.
Selenium	See SELENIUM plus Potassium.
Selenium Monochloride	When potassium is added to selenium monochloride at ordinary temperatures, the mixture explodes violently.
	Mellor **10:** 896 (1946-1947).
	Mellor **2, Supp. 3:** 1564 (1963).
Selenium Oxychloride	When potassium is brought in contact with selenium oxychloride in the cold, a violent explosion occurs.
	Mellor **10:** 908 (1946-1947).
Silicon Tetrachloride	See POTASSIUM plus Aluminum Bromide.
Silver Bromide	See SODIUM plus Silver Bromide.
Silver Chloride	See SODIUM plus Silver Bromide.
	See POTASSIUM plus Ammonium Bromide.
Silver Fluoride	See SODIUM plus Silver Bromide.
	See POTASSIUM plus Aluminum Bromide.
Silver Iodate	See POTASSIUM plus Boric Acid.
Silver Iodide	See SODIUM plus Silver Bromide.
	See POTASSIUM plus Ammonium Bromide.

Sodium Iodate	See POTASSIUM plus Boric Acid.
Sodium Nitrite and Ammonia	Solutions of potassium and sodium nitrite in liquid ammonia form disodium nitrite, which is very reactive and easily explosive.
	Mellor **2, Supp. 3:** 1566 (1963).
Sodium Peroxide	Sodium peroxide oxidizes potassium with incandescence.
	Mellor **2:** 490-93 (1946-1947).
Stannic Chloride	See POTASSIUM plus Aluminum Bromide.
Stannic Iodide and Sulfur	See POTASSIUM plus Aluminum Bromide.
Stannic Oxide	Stannic oxide is reduced by potassium or sodium at gentle heat and the reaction is accompanied by incandescence.
	Mellor **7:** 401 (1946-1947).
Stannous Chloride	See POTASSIUM plus Aluminum Bromide.
Strontium Iodide	See POTASSIUM plus Ammonium Bromide.
Sulfur	Vapors of potassium and sulfur react with chemiluminescence at 300¡ C and low pressures.
	Mellor **2, Supp. 3:** 1564 (1963).
Sulfur Dibromide	See POTASSIUM plus Aluminum Bromide.
Sulfur Dichloride	See POTASSIUM plus Boron Tribromide.
Tellurium	See TELLURIUM plus Potassium.
Tetrachloroethane	See SODIUM plus Tetrachloroethane.
Thallous Bromide	See POTASSIUM plus Aluminum Bromide.
Thallous Chloride	See POTASSIUM plus Ammonium Bromide.
Thiophosphoryl Fluoride	See SODIUM plus Thiophosphoryl Fluoride.
Titanium Tetrachloride	During the reduction of titanium tetrachloride to titanium metal with potassium, an explosion occurred. Prior to the explosion, the system was heated to 90¡C.

	Waller and Mandell (1967).
Vanadium Oxychloride	See POTASSIUM plus Boric Acid.
Vanadium Pentachloride	See POTASSIUM plus Aluminum Bromide.
Water	At 20¡C. the heat of reaction is adequate to ignite the hydrogen liberated.
	Mellor **2:** 469 (1946-1947).
	Mellor **2, Supp. 3:** 1560 (1963).
Zinc Bromide	See POTASSIUM plus Aluminum Bromide.
Zinc Chloride	See POTASSIUM plus Aluminum Bromide.
Zinc Fluoride	See POTASSIUM plus Ammonium Bromide.
Zinc Iodide	See POTASSIUM plus Aluminum Bromide.

POTASSIUM ACETYLIDE KC≡H

Carbon Dioxide	When potassium acetylene carbide is warmed with carbon dioxide, the mass becomes incandescent.
	Mellor **5:** 849-50 (1946-1947).
Chlorine	See CHLORINE plus Potassium Acetylene Carbide.
Sulfur Dioxide	Potassium acetylene carbide reacts with sulfur dioxide at ordinary temperatures and it becomes incandescent.
	Mellor **5:** 849 (1946-1947).

POTASSIUM ACI-NITROACETATE $K_2O_2N{=}CHCHO$

Water	Dipotassium nitroacetate exploded when the dry salt was moistened with a little water.
	Chem. Eng. News **27:** 1473.

POTASSIUM ACI-NITROMETHYLIDE KCH_2NO_2

(See SODIUM NITROMETHANE)

POTASSIUM AMIDE KNH_2

Water	Potassium amide reacts vigorously with water and may be accompanied by ignition.
	Mellor **8:** 255 (1946-1947).

POTASSIUM AZIDE KN_3

Carbon Disulfide	See CARBON DISULFIDE plus Azides.
Manganese Dioxide	See MANGANESE DIOXIDE plus Potassium Azide.

POTASSIUM AZIDODISULFATE KSO_3OSO_2NNN

Water	This reaction is an explosive one.
	Mellor **8, Supp. 2:** 36 (1967).

POTASSIUM BICARBONATE $KHCO_3$

Monoammonium Phosphate	See SODIUM BICARBONATE plus Monoammonium Phosphate.

POTASSIUM BOROHYDRIDE

(See POTASSIUM TETRAHYDROBORATE)

POTASSIUM BROMATE $KBrO_3$

Aluminum	See ALUMINUM plus Bromates.
Arsenic	See ARSENIC plus Bromates.
Carbon	See CARBON plus Bromates.
Copper	See COPPER plus Bromates.

Lead Acetate	During an attempt to make lead bromate, an explosion occurred that caused two deaths.
	Mellor **2, Supp. 1:** 770 (1956).
Metal Sulfides	See METAL SULFIDES plus Bromates.
Organic Matter	See BROMATES plus Organic Matter.
Phosphorus	See PHOSPHORUS plus Bromates.
Selenium	See SELENIUM plus Potassium Bromate.
Sulfur	See SULFUR plus Bromates.

POTASSIUM BROMIDE KBr

Bromine Trifluoride	See BROMINE TRIFLUORIDE plus Potassium Bromide.

POTASSIUM tert.-BUTOXIDE $KOC(CH_3)_3$

Acetic Acid	See ACETONE plus Potassium Tert.-Butoxide.
Acetone	See ACETONE plus Potassium Tert.-Butoxide.
Butyl Acetate	See ACETONE plus Potassium Tert.-Butoxide.
Carbon Tetrachloride	See ACETONE plus Potassium Tert.-Butoxide.
Chloroform	See ACETONE plus Potassium Tert.-Butoxide.
Diethyl Sulfate	See ACETONE plus Potassium Tert.-Butoxide.
Dimethyl Carbonate	See ACETONE plus Potassium Tert.-Butoxide.
Epichlorohydrin	See ACETONE plus Potassium Tert.-Butoxide.
Ethyl Acetate	See ACETONE plus Potassium Tert.-Butoxide.
Ethyl Alcohol	See ACETONE plus Potassium Tert.-Butoxide.
Isopropyl Alcohol	See ACETONE plus Potassium Tert.-Butoxide.
Methyl Alcohol	See ACETONE plus Potassium Tert.-Butoxide.
Methylene Chloride	See ACETONE plus Potassium Tert.-Butoxide.
Methyl Ethyl Ketone	See ACETONE plus Potassium Tert.-Butoxide.

Methyl Isobutyl Ketone	See ACETONE plus Potassium Tert.-Butoxide.
Propyl Alcohol	See ACETONE plus Potassium Tert.-Butoxide.
Propyl Formate	See ACETONE plus Potassium Tert.-Butoxide.
Sulfuric Acid	See ACETONE plus Potassium Tert.-Butoxide.

POTASSIUM CARBIDE K_2C_2

Water	Potassium carbide may react explosively on contact with water. *Bahme*, p. 27 (1961).

POTASSIUM CARBONATE K_2CO_3

Chlorine Trifluoride	See CHLORINE TRIFLUORIDE plus Nitric Acid.

POTASSIUM CARBONYL KCO

Air	See SODIUM CARBONYL plus Air.
Oxygen	See POTASSIUM plus Carbon Monoxide and Oxygen.
Water	See SODIUM CARBONYL plus Air.

POTASSIUM CHLORATE $KClO_3$

Aluminum	See ALUMINUM plus Bromates.
Ammonia	Gaseous ammonia, mixed with air reacts so vigorously with potassium chlorate that the reaction may become dangerous. *Mellor* **8:** 217 (1946-1947).
Ammonium Chloride	In the manufacture of signaling smokes this combination is hazardous because of metathetical interaction to form unstable ammonium perchlorate. *Ellern*, p. 155 (1968).

	See POTASSIUM CHLORATE plus Ammonium Salts.
Ammonium Salts	The reaction of potassium chlorate with ammonium salts is violent.
	Mellor **2, Supp. 1:** 586 (1956).
Ammonium Sulfate	The mixture of potassium chlorate and ammonium sulfate decomposes with incandescence when heated.
	Mellor **2:** 702 (1946-1947).
Antimony Trisulfide	A mixture of potassium chlorate and antimony trisulfide can be exploded by an electric spark.
	Mellor **9:** 523 (1946-1947).
Arsenic	See ARSENIC plus Bromates.
Barium Hypophosphite	A mixture of equal parts of these materials, previously dried at 100¡ C., burns in open air with great rapidity. When the mixture is confined, an explosion will result. The mixture is very sensitive to shock and friction.
	Mellor **8:** 881 (1946-1947).
Barium Sulfide	See BARIUM SULFIDE plus Potassium Chlorate.
Boron	See BORON plus Potassium Chlorate.
Calcium Hypophosphite	See CALCIUM HYPOPHOSPHITE plus Potassium Chlorate.
Calcium Sulfide	See BARIUM SULFIDE plus Lead Dioxide.
Carbon	See CARBON plus Bromates.
Charcoal	See CHLORATES plus Organic Matter.
Chromium	See CHROMIUM plus Potassium Chlorate.
Copper	See COPPER plus Bromates.
Copper Phosphide	See COPPER PHOSPHIDE plus Potassium Chlorate.
Gallic Acid	Gallic acid, potassium chlorate and red gum (Formula 156) is a pyrotechnic whistle composition.
	Ellern, p. 183 (1968).
Germanium	See GERMANIUM plus Potassium Nitrate.

Hydrogen Iodide	Molten potassium chlorate ignites in hydrogen iodide.
	Mellor **2:** 204 (1946-1947).
Magnesium	See MAGNESIUM plus Potassium Chlorate.
Magnesium, Copper Sulfate (anhydrous), Ammonium Nitrate and Water	See MAGNESIUM plus Copper Sulfate (anhydrous), Ammonium Nitrate, Potassium Chlorate and Water.
Manganese Dioxide	See CHLORATES plus Manganese Dioxide.
Mercury Tetratriphosphide	See MERCURY TETRATRIPHOSPHIDE plus Air.
Metal Sulfides	See METAL SULFIDES plus Bromates.
Organic Acids (Dibasic)	See CHLORATES plus Organic Acids.
Organic Matter	See BROMATES plus Organic Matter. See also CHLORATES plus Organic Matter.
Phosphorus	See PHOSPHORUS plus Potassium Chlorate.
	See PHOSPHORUS plus Bromates.
Silver Sulfide	A violent reaction occurs when silver sulfide is heated with potassium chlorate.
	Mellor **3:** 447 (1946-1947).
Sodium Amide	A mixture of sodium amide and potassium chlorate explodes.
	Mellor **8:** 258 (1946-1947).
Sulfur	See SULFUR plus Bromates. See CHLORATES plus Organic Matter.
	See SULFUR plus Potassium Chlorate.
Sulfur Dioxide	If a drop of a solution of sulfur dioxide in ether or alcohol is added to powdered potassium chlorate, a reaction ensues and the mass explodes.
	Mellor **2:** 311 (1946-1947).
Sulfuric Acid	These materials may react to cause fires and possible explosions.

	Mellor **2:** 315 (1946-1947).
Thiocyanates	See THIOCYANATES plus Chlorates.
Titanium	See TITANIUM plus Potassium Chlorate.
Zinc	See ZINC plus Chlorates.
Zirconium	See ZIRCONIUM plus Potassium Chlorate.

POTASSIUM CHLORIDE KCl

Bromine Trifluoride	See BROMINE TRIFLUORIDE plus Potassium Bromide.
Potassium Permanganate and Sulfuric Acid	See POTASSIUM PERMANGANATE plus Sulfuric Acid and Potassium Chloride.

POTASSIUM CYANIDE KCN

Chlorates	See POTASSIUM CYANIDE plus Sodium Chlorate.
Nitrites	See NITRITES plus Potassium Cyanide.
Nitrogen Trichloride	See NITROGEN TRICHLORIDE plus Ammonia.
Sodium Chlorate	Chlorates plus potassium cyanide explode when heated.
	Von Schwartz, p. 323 (1918). *Pieters,* p. 30 (1957).

POTASSIUM DICHROMATE $K_2Cr_2O_7$

Acetone and Sulfuric Acid	See ACETONE plus Sulfuric Acid and Potassium Dichromate.
Hydrazine	Potassium dichromate or sodium dichromate reacts explosively with hydrazine.
	Mellor **11:** 234 (1946-1947).
Hydroxylamine	A drop of anhydrous hydroxylamine on powdered potassium dichromate produces a violent explosion.
	Mellor **8:** 293 (1946-1947).

POTASSIUM DIHYDROPHOSPHIDE KPH_2

(self-reactive)	See POTASSIUM plus Phosphine and Ammonia.

POTASSIUM FERRICYANIDE $K_3Fe(CN)_6$

Ammonia	A mixture of the two may cause an explosion.
	Pieters, p. 30 (1957).
Chromic Anhydride	See CHROMIC ANHYDRIDE plus Potassium Ferricyanide.

POTASSIUM FERROCYANIDE $K_4Fe(CN)_6 \cdot 3H_2O$

Cupric Nitrate	See CUPRIC NITRATE plus Potassium Ferrocyanide.

POTASSIUM FLUORIDE KF

Platinum and Bromine Trifluoride	See PLATINUM plus Bromine Trifluoride and Potassium Fluoride.

POTASSIUM GRAPHITE KC_8; KC_{24}

Air	Potassium graphite is spontaneously flammable in air.
	Brauer (1965).

POTASSIUM HEXAHYDROALUMINATE K_3AlH_6

(self-reactive)	A sample of this hydride over a period of months oxidized or hydrolized. The product of this reaction when scraped with a metal spatula exploded violently. Cesium hexahydroaluminate behaves similarly.
	Chem. Eng. News **47** (1): 9 (1969).

POTASSIUM HYDRIDE KH

Air	Potassium hydride is spontaneously flammable in air.
	Coates, p. 161 (1956). *Ellern* (1961).
Chlorine	See CHLORINE plus Potassium Hydride.
Fluorine	See CHLORINE plus Potassium Hydride.

POTASSIUM HYDROXIDE KOH

(See also SODIUM HYDROXIDE)

Acetic Acid	See ACETIC ACID plus Potassium Hydroxide.
Acrolein	See SODIUM HYDROXIDE plus Acrolein.
Acrylonitrile	See SODIUM HYDROXIDE plus Acrylonitrile.
Calcium Carbide and Chlorine	See DICHLOROACETYLENE plus Air.
Chlorine Dioxide	A piece of potassium hydroxide causes liquid chlorine dioxide to explode.
	Mellor **2:** 289 (1946-1947).
Chlorine and Hydrogen Peroxide	See CHLORINE plus Hydrogen Peroxide and Potassium Hydroxide.
Chloroform and Methyl Alcohol	See SODIUM HYDROXIDE plus Chloroform and Methyl Alcohol.
1,2-Dichloroethylene	The reaction produces chloroacetylene, which is explosive and spontaneously flammable in air. It is highly toxic.
	Rutledge, p. 134 (1968).
	See also SODIUM plus 1,2-Dichloroethylene.
Maleic Anhydride	See SODIUM HYDROXIDE plus Maleic Anhydride.
N-Methyl-N-Nitroso Urea and Methylene Chloride	See N-METHYL-N-NITROSO UREA plus Potassium Hydroxide and Methylene Chloride.

Nitroethane	See CALCIUM HYDROXIDE plus Nitroethane.
Nitrogen Trichloride	See NITROGEN TRICHLORIDE plus Ammonia.
Nitromethane	See CALCIUM HYDROXIDE plus Nitroethane.
Nitroparaffins	See CALCIUM HYDROXIDE plus Nitroethane.
o-Nitrophenol	Molten ortho nitrophenol reacts violently with potassium hydroxide (commercial 85% pellets).
	Pouwels (1972).
Nitropropane	See CALCIUM HYDROXIDE plus Nitroethane.
N-Nitrosomethylurea	A reaction between n-nitrosomethylurea and potassium hydroxide in n-butyl ether resulted in an explosion due to the formation of diazomethane.
	Schwab (1972).
Nitrosomethyl Urea and Methylene Chloride	See NITROSOMETHYL UREA plus Potassium Hydroxide and Methylene Chloride.
Phosphorus	See PHOSPHORUS plus Alkaline Hydroxides and PHOSPHORUS plus Potassium Hydroxide.
Potassium Persulfate and Water	See POTASSIUM PERSULFATE plus Potassium Hydroxide and Water.
Sodium Azide and Benzoyl Chloride	See SODIUM AZIDE plus Benzoyl Chloride and Potassium Hydroxide.
Tetrachloroethane	When solid potassium hydroxide and tetrachloroethane are heated, a spontaneously flammable gas, chloroacetylene, is formed.
	Bahme, p. 33 (1961).
Tetrahydrofuran	See TETRAHYDROFURAN plus Potassium Hydroxide.
Trichloroethylene	See SODIUM HYDROXIDE plus Trichloroethylene.
Water	See POTASSIUM OXIDE plus Water.

POTASSIUM HYPOBORATE $K_4B_2O_4$

(self-reactive)	Potassium hypoborate is a stronger, more violent reducing agent than potassium hypophosphite. *Mellor* **5:** 37 (1946-1947).

POTASSIUM HYPOPHOSPHITE KH_2PO_2

(self-reactive)	Potassium hypophosphite decomposes when heated, forming phosphine, a spontaneously flammable gas. *Mellor* **8:** 881 (1946-1947).
Nitric Acid	Potassium hypophosphite explodes when evaporated with nitric acid. *Mellor* **8:** 882 (1946-1947).

POTASSIUM IODATE KIO_3

Aluminum	See ALUMINUM plus Bromates.
Arsenic	See ARSENIC plus Bromates.
Carbon	See CARBON plus Bromates.
Copper	See COPPER plus Bromates.
Metal Sulfides	See METAL SULFIDES plus Bromates.
Organic Matter	See BROMATES plus Organic Matter.
Phosphorus	See PHOSPHORUS plus Potassium Iodate.
Sulfur	See SULFUR plus Bromates.

POTASSIUM IODIDE KI

Bromine Trifluoride	See BROMINE TRIFLUORIDE plus Potassium Bromide.
Chlorine Trifluoride	See CHLORINE TRIFLUORIDE plus Nitric Acid.
Fluorine Perchlorate	See FLUORINE PERCHLORATE plus Potassium Iodide.

POTASSIUM MERCURICYANIDE

(See POTASSIUM TRICYANOMERCURATE)

POTASSIUM NITRATE KNO_3

Antimony	See ANTIMONY plus Potassium Nitrate.
Antimony Trisulfide	A mixture of potassium nitrate and antimony trisulfide explodes at a red heat.
	Mellor **9:** 524 (1946-1947).
Arsenic	See ARSENIC plus Potassium Nitrate.
Arsenic Disulfide	Arsenic disulfide forms explosive nixtures when mixed with potassium nitrate.
	Mellor **9:** 270 (1946-1947).
Barium Sulfide	See BARIUM SULFIDE plus Lead Dioxide.
Boron	See BORON plus Potassium Nitrate.
Boron Phosphide	See BORON PHOSPHIDE plus Nitric Acid.
Calcium Sulfide	See BARIUM SULFIDE plus Lead Dioxide.
Charcoal	Charcoal and potassium nitrate make a pyrotechnic mixture.
	Ellern, p. 378 (1968).
Copper Phosphide	See COPPER PHOSPHIDE plus Potassium Nitrate.
Fluorine	See FLUORINE plus Potassium Nitrate.
Germanium	See GERMANIUM plus Potassium Nitrate.
Germanium Sulfide	See GERMANIUM SULFIDE plus Potassium Nitrate.
Sodium Acetate	A mixture of the two may cause an explosion.
	Pieters, p. 30 (1957).
Sodium Hypophosphite	A mixture of potassium nitrate and sodium hypophosphite constitutes a powerful explosive.
	Mellor **8:** 881 (1946-1947).

Sodium Peroxide and Dextrose	See SODIUM PEROXIDE plus Dextrose and Potassium Nitrate.
Sulfur and Arsenic Trisulfide	See SULFUR plus Potassium Nitrate and Arsenic Trisulfide.
Titanium	See TITANIUM plus Potassium Chlorate.
Titanium Disulfide	See TITANIUM DISULFIDE plus Potassium Nitrate.
Trichloroethylene	See TRICHLOROETHYLENE plus Potassium Nitrate.
Zinc	See ZINC plus Potassium Nitrate.
Zirconium	See ZIRCONIUM plus Potassium Nitrate.

POTASSIUM p-NITROBENZENE-DIAZOSULFONATE
$O_2N\text{-}C_6H_4\text{-}4\text{-}N{=}NSO_3K$

(self-reactive)

While a chemist was examining some crystals of potassium p-nitrobenzene-diazosulfonate with a loupe, the entire 10-gram batch, which was on a sheet of filter paper, exploded. The crystals were probably the "labile" form (potassium p-nitrobenzene-syn-diazosulfonate) and would have in time converted to the "stable" form.

Crucible **58** (9): 147 (1973).

POTASSIUM NITRIDE K_3N

Air

Potassium nitride generally ignites spontaneously when exposed to air.

Mellor **8:** 99 (1946-1947).

Phosphorus

See PHOSPHORUS plus Potassium Nitride.

POTASSIUM NITRITE KNO_2

Ammonium Sulfate

When a little ammonium sulfate is added to fused potassium nitrite, a vigorous reaction occurs attended by flame.

	Mellor **2:** 702 (1946-1947).
Boron	See BORON plus Potassium Nitrite.

POTASSIUM OXIDE K_2O

Water	The oxides of sodium or potassium react with water vigorously and with enough evolution of heat to cause boiling and spattering of hot caustic solution.
	Chem. Safety Data Sheets **SD-9, SD-10** (1947).

POTASSIUM OXIDES KxOy

Potassium	See POTASSIUM plus Air.
Sodium	See POTASSIUM plus Air.
Sodium-Potassium Alloy	See POTASSIUM plus Air.
Organic Matter	See POTASSIUM plus Air.

POTASSIUM OZONIDE KO_3

Potassium	See POTASSIUM plus Potassium Ozonide.
Sodium	See SODIUM plus Potassium Ozonide.
Water	Both potassium ozonide and potassium superoxide react explosively with water. Both are too unstable to be isolated.
	Mellor **2, Supp. 3:** 1631 (1963).

POTASSIUM PERCHLORATE $KClO_4$

Aluminum and Magnesium	See ALUMINUM plus Magnesium and Potassium Perchlorate.
Charcoal	See PERCHLORATES plus Charcoal.

Fluorine	See FLUORINE plus Potassium Perchlorate.
Magnesium	See MAGNESIUM plus Potassium Perchlorate.
Nickel and Titanium	See NICKEL plus Titanium and Potassium Perchlorate.
Reducing Agents	See PERCHLORATES plus Charcoal.
Sulfur	See SULFUR plus Potassium Perchlorate.

POTASSIUM PERMANGANATE $KMnO_4$

Aluminum Carbide	See ALUMINUM CARBIDE plus Potassium Permanganate.
Antimony	See ANTIMONY plus Potassium Permanganate.
Arsenic	See ANTIMONY plus Potassium Permangnate.
Dimethyl Sulfoxide	See DIMETHYL SULFOXIDE plus Potassium Permanganate.
Glycerol	Contact between the two may produce an explosion.
	Pieters, p. 30 (1957).
Hydrogen Peroxide	Potassium permanganate can produce an explosion when brought into contact with very concentrated hydrogen peroxide.
	Haz. Chem. Data, p. 230 (1973).
Hydrogen Trisulfide	See HYDROGEN TRISULFIDE plus Potassium Permanganate.
Hydroxylamine	When solid hydroxylamine is brought into contact with solid potassium permanganate, there is produced immediately a white flame.
	Mellor **8:** 294 (1946-1947).
Organic Matter	An explosive reaction can occur when solid, finely divided potassium permanganate comes in contact with organic substances.
	Pascal 16: 1041 (1931-1934). *Pieters,* p. 28 (1957). *Haz. Chem. Data,* p. 230 (1973).

Phosphorus	See PHOSPHORUS plus Potassium Permanganate.
Polypropylene	Potassium permanganate being conveyed through a polypropylene tube ignited the tube.
	MCA Case History **1842** (1972).
Sulfur	See SULFUR plus Potassium Permanganate.
Sulfuric Acid	An explosion occurred when concentrated sulfuric acid was mixed with crystalline potassium permanganate in a vessel containing moisture. Manganese heptoxide was formed, which is explosive at 70¡ C.
	Delhez (1967).
	J. R. Archer, *Chem. Eng. News* **26:** 205 (1948). Permanganate anhydride, Mn_2O_7, forms in the course of the reaction of concentrated sulfuric acid with crystallized potassium permanganate at low temperature (minus 20¡ C). An oily liquid forms under the layer of sulfuric acid that is very unstable and detonates when the temperature is increased (70¡ C).
	RŸst and Ebert, p. 29 (1948). *Pieters,* p. 28 (1957). *Gallais,* pp. 696, 697 (1957).
Sulfuric Acid and	When potassium permanganate is dissolved in
Organic Matter	95% sulfuric acid, a green solution of permanganyl sulfate is formed. This solution will oxidize most organic compounds and, if the solution is strongly concentrated, explosion may accompany the oxidation.
	Waller and Mandell (1967).
Sulfuric Acid and	An attempt to prepare permanganyl chloride,
Potassium Chloride	MnO_3Cl, by adding cautiously, concentrated sulfuric acid to an intimate mixture of potassium permanganate and potassium chloride kept at 0¡C in clean all-glass apparatus resulted in a violent explosion.
	Delhez (1967).
Titanium	See TITANIUM plus Potassium Chlorate.

POTASSIUM PEROXIDE K_2O_2

(See also SODIUM PEROXIDE)

Air	See POTASSIUM PEROXIDE plus Water.
Antimony	See POTASSIUM plus Potassium Peroxide.
Arsenic	See POTASSIUM plus Potassium Peroxide.
Oxygen	See OXYGEN plus Potassium Peroxide.
Potassium	See POTASSIUM plus Potassium Peroxide and POTASSIUM plus Potassium Tetroxide.
Water	Potassium peroxide is very reactive, and can explode in air or water.
	Mellor **2, Supp. 3:** 1577 (1963).

POTASSIUM PERSULFATE $K_2S_2O_3$

Potassium Hydroxide	Potassium persulfate plus a little potassium
and Water	hydroxide and water ignited a polythene (polyethylene) liner of a container by simultaneous release of heat and oxygen.
	MCA Case History **1155** (1955).

POTASSIUM PHOSPHIDE K_3P

Water	Potassium phosphide reacts with water to form spontaneously flammable phosphine.
	Van Wazer (1958).

POTASSIUM SILICIDE K_2Si_2

Acids	See POTASSIUM SILICIDE plus Water.
Air	Potassium silicide is spontaneously flammable in air and may explode.
	Ellern (1961).

Water	Potassium silicide ignites spontaneously on contact with water or dilute acids.
	Brauer (1965).
	See also CESIUM SILICIDE plus Water.

POTASSIUM SULFATE K_2SO_4

Aluminum	See ALUMINUM plus Sulfates.

POTASSIUM SUPEROXIDE KO_2

Ethyl Alcohol	To dispose of a piece of sodium-potassium waste, it was placed in a glove box, which was then purged with argon for 10 minutes. When 10 ml of alcohol was added to the waste, an immediate pressure rise caused the glove to burst and flame issued from the port. Also, a highly oxidized sphere of potassium was cut in two and one half was dropped into a dish of alcohol; an immediate explosion shattered the dish. Potassium superoxide was considered the cause of both incidents.
	Health and Safety Inf. **251** (March 31, 1967).
Graphite	Potassium superoxide forms on the surface of either solid or molten potassium metal. Attempts to extinguish burning potassium with powdered graphite have resulted in violent explosions.
	Chem. Abst. **63:** 424 (1965).
Oil	Stainless steel pots containing traces of sodium-potassium alloy were immersed in oil to await cleaning. During removal of the lid from one pot, an explosion occurred that was attributed to long-term formation of potassium superoxide, which reacted with the oil when it was disturbed.
	Health and Safety Inf. **251** (March 31, 1967).
Potassium	See POTASSIUM plus Potassium Superoxide.
Selenium Monochloride	See SELENIUM MONOCHLORIDE plus Potassium Superoxide.

Sodium	See SODIUM plus Potassium Ozonide.
Sodium-Potassium Alloy	See SODIUM-POTASSIUM ALLOY plus Potassium Superoxide.
Water	See POTASSIUM OZONIDE plus Water.

POTASSIUM TETRACHLOROCUPRATE K_2CuCl_4

Potassium	See POTASSIUM plus Ammonium Bromide.

POTASSIUM TETRAETHYNYLNICKELATE $K_4[Ni(CCH)_4]$

Air	Tetraacetenyl nickel tetrapotassium is spontaneously flammable in air. *Kaufman* (1961).

POTASSIUM TETRAHYDROBORATE

Air	Potassium borohydride burns quietly in air. *Lab. Govt. Chemist* (1965).

POTASSIUM TETRAPEROXYCHROMATE $K_3Cr(OO)_4$

(self-reactive)	Potassium triperchromate decomposes explosively at 178¡ C. The impure salt is explosive. *Mellor* **11:** 356 (1946-1947).

POTASSIUM TETROXIDE K_2O_4

(See POTASSIUM SUPEROXIDE KO_2)

POTASSIUM TRICYANOMERCURATE $KHg(CN)_3$

Ammonia	A mixture of the two may cause an explosion.
	Pieters, p. 30 (1957).

PRASEODYMIUM Pr

Air	See RARE EARTH METALS plus Air.
Halogens	See RARE EARTH METALS plus Halogens.

PROPANE $CH_3CH_2CH_3$

Chlorine Dioxide	See CHLORINE DIOXIDE plus Butadiene.

PROPANE-1,2-DIAMINE PERCHLORATE

$CH_3CH(NH_2)CH_2NH_2 \bullet (ClO_4)_2$

(self-reactive)	This compound is an explosive that exceeds the power and brisance of TNT.
	ACS **146:** 206. *Chem. Reviews* **44:** 419-45 (1949).

PROPANE-1,3-DIAMINE PERCHLORATE

$CH_2(NH_2)CH_2CH_2NH(ClO_4)_2$

(self-reactive)	This compound is an explosive that exceeds the power and brisance of TNT.
	ACS **146:** 206. *Chem. Reviews* **44:** 419-45 (1949).

1-PROPANETHIOL C_3H_7SH

Calcium Hypochlorite	See CALCIUM HYPOCHLORITE plus 1-Propanethiol.
	See CALCIUM HYPOCHLORITE plus Mercaptan.

PROPARGYL ALCOHOL

(See 2-PROPYN-1-OL)

PROPARGYL BROMIDE

(See 3-BROMO-1-PROPYNE)

PROPARGYL CHLORIDE

(See 3-CHLORO-1-PROPYNE)

PROPIOLACTONE (beta-)

2-Aminoethanol	See 2-AMINOETHANOL plus Propiolactone.
Ammonium Hydroxide	Mixing propiolactone (beta-) and 28% ammonium hydroxide in a closed container caused the temperature and pressure to increase. *Flynn and Rossow* (1970). See Note under complete reference.
Aniline	See ANILINE plus Propiolactone.
Chlorosulfonic Acid	Mixing propiolactone (beta-) and chlorosulfonic acid in a closed container caused the temperature and pressure to increase. *Flynn and Rossow* (1970). See Note under complete reference.
Ethylene Diamine	See ETHYLENE DIAMINE plus Propiolactone (beta-).
Ethyleneimine	See ETHYLENEIMINE plus Propiolactone (beta-).
Hydrochloric Acid	Mixing propiolactone (beta-) and 36% hydrochloric acid in a closed container caused the temperature and pressure to increase. *Flynn and Rossow* (1970). See Note under complete

	reference.
Hydrofluoric Acid	Mixing propiolactone (beta-) and 48.7% hydrofluoric acid in a closed container caused the temperature and pressure to increase.
	Flynn and Rossow (1970). See Note under complete reference.
Nitric Acid	Mixing propiolactone (beta-) and 70% nitric acid in a closed container caused the temperature and pressure to increase.
	Flynn and Rossow (1970). See Note under complete reference.
Oleum	See OLEUM plus Propiolactone (beta-).
Pyridine	See PYRIDINE plus Propiolactone (beta-).
Sodium Hydroxide	See SODIUM HYDROXIDE plus Propiolactone (beta-).
Sulfuric Acid	Mixing propiolactone (beta-) and 96% sulfuric acid in a closed container caused the temperature and pressure to increase.
	Flynn and Rossow (1970). See Note under complete reference.

PROPYL ALCOHOL $CH_3CH_2CH_2OH$

Potassium Tert.-Butoxide	See ACETONE plus Potassium Tert.-Butoxide.

PROPYLENE $H_3CCH{=}CH_2$

Nitrogen Dioxide	See NITROGEN TETROXIDE plus Olefins.
Nitrogen Tetroxide	See NITROGEN TETROXIDE plus Propylene.
Nitrous Oxide	See NITROUS OXIDE plus Propylene.

1,2-PROPYLENEDIAMINE DIPERCHLORATE

(See PROPANE-1,2-DIAMINE PERCHLORATE)

1,3-PROPYLENEDIAMINE DIPERCHLORATE

(See PROPANE-1,3-DIAMINE PERCHLORATE)

PROPYLENE DICHLORIDE

(See 1,2-DICHLOROPROPANE)

PROPYLENE OXIDE

Ammonium Hydroxide	Mixing propylene oxide and 28% ammonium hydroxide in a closed container caused the temperature and pressure to increase.
	Flynn and Rossow (1970). See Note under complete reference.
Chlorosulfonic Acid	Mixing propylene oxide and chlorosulfonic acid in a closed container caused the temperature and pressure to increase.
	Flynn and Rossow (1970). See Note under complete reference.
Hydrochloric Acid	Mixing propylene oxide and hydrochloric acid in a closed container caused the temperature and pressure to increase.
	Flynn and Rossow (1970). See Note under complete reference.
Hydrofluoric Acid	Mixing propylene oxide and 48.7% hydrofluoric acid in a closed container caused the temperature and pressure to increase.
	Flynn and Rossow (1970). See Note under complete reference.
Nitric Acid	Mixing propylene oxide and 70% nitric acid in a closed container caused the temperature and pressure to increase.
	Flynn and Rossow (1970). See Note under complete

	reference.
Oleum	See OLEUM plus Propylene Oxide.
Sulfuric Acid	Mixing propylene oxide and 96% sulfuric acid in a closed container caused the temperature and pressure to increase. *Flynn and Rossow* (1970). See Note under complete reference.

PROPYL FORMATE C_3H_7OCHO

Potassium Tert.-Butoxide	See ACETONE plus Potassium Tert.-Butoxide.

PROPYLLITHIUM C_3H_7Li

Air	Propyl lithium is spontaneously flammable in air. *Ellern* (1961).

PROPYL PERCHLORATE $C_3H_7ClO_4$

(self-reactive)	See METHYL PERCHLORATE (self-reactive).

PROPYLSILANE $C_3H_7SiH_3$

Air	Propyl silane is spontaneously flammable in air. *Kaufman* (1961).

PROPYNE $CH_3C{=}CH$

(self-reactive)	Methyl acetylene can decompose explosively at 4.5-5.6 atmospheres pressure. *Rutledge*, p. 13 (1968).

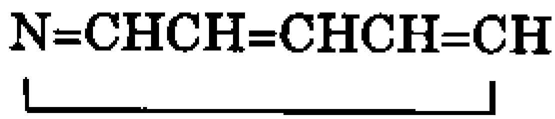
2-PROPYN-1-OL $CH{\equiv}CCH_2OH$

Phosphorus Pentoxide	See PHOSPHORUS PENTOXIDE plus Propargyl Alcohol.

PROSILOXANE

(See OXOSILANE)

PYRIDINE



Chlorosulfonic Acid	Mixing pyridine and chlorosulfonic acid in a closed container caused the temperature and pressure to increase. *Flynn and Rossow* (1970). See Note under complete reference.
Chromium Trioxide	See CHROMIC ANHYDRIDE plus Pyridine.
Maleic Anhydride	See MALEIC ANHYDRIDE plus Pyridine.
Nitric Acid	Mixing pyridine and 70% nitric acid in a closed container caused the temperature and pressure to increase. *Flynn and Rossow* (1970). See Note under complete reference.
Oleum	See OLEUM plus Pyridine.
Perchromates	See PERCHROMATES plus Pyridine.
Propiolactone (beta-)	Mixing pyridine and propiolactone (beta-) in a closed container caused the temperature and pressure to increase. *Flynn and Rossow* (1970). See Note under complete reference.
Silver Perchlorate	See SILVER PERCHLORATE plus Acetic Acid. See SILVER PERCHLORATE plus Toluene.
Sulfuric Acid	Mixing pyridine and 96% sulfuric acid in a closed container caused the temperature and pressure to increase. *Flynn and Rossow* (1970). See Note under complete

reference.

PYRIDINIUM PERCHLORATE $(C_5H_6N)ClO_4$

(self-reactive)

This salt may explode violently in contact with metals.

Mellor **2, Supp. 1:** 603 (1956).

Pyridine perchlorate decomposes or explodes when heated above 335¡ C. The kindling temperature is lowered by the addition of ammonium perchlorate.

ACS **146:** 213 (1960). *Chemiker.Ztg.* **74:** 139-40 (1950).

3-PYRIDYLDIAZONIUM FLUOROBORATE $NC_5H_4N(\equiv N)BF_4$

(self-reactive)

Following a procedure described in the literature for the preparation of this salt, several grams were spread on aluminum foil to dry. A small portion was removed to determine its decomposition point in a glass capillary. It exploded at 47¡ C. The remaining material exploded while sitting on the aluminum foil.

Chem. Eng. News **45** (41): 44 (1967); **45** (51):**8** (1967).

QUICKLIME CaO

(See CALCIUM OXIDE)

QUINOLINE

Perchromates

See PERCHROMATES plus Quinoline.

RARE EARTH HYDRIDES

Air and Water	The hydrides of the rare earths are stable in dry air, but ignite in moist air.
	Hampel, pp. 407-8 (1961).

RARE EARTH METALS

Air	The rare earth metals ignite in air at 302 to 356¡ F., but lanthanum ignites at 824 to 860¡ F. With oxide impurities present, however, the rare earth metals are pyrophoric on cutting and filing.
	Hampel, pp. 407-8 (1961).
Halogens (Vapor)	Rare earth metals burn vigorously in halogen vapors above 392¡ F.
	Hampel, pp. 407-8 (1961).

RHENIUM Re

Flourine	Rhenium and fluorine react readily at 125¡ C.
	Mellor **2, Supp. 1:** 64 (1956).

RHODIUM Rh

Chlorine Trifluoride	See ANTIMONY plus Chlorine Trifluoride.
Oxygen Difluoride	See IRIDIUM plus Oxygen Diflouride.

RHODIUM-AMMINE NITRATES

(self-reactive)	Rhodium-ammine nitrates may be impact-sensitive. $Rh(NH_3)_5I(NO_3)_2$ crystals explode when heated.
	Mellor **15:** 590 (1946-1947).

RHODIUM-AMMINE PERCHLORATES

(self-reactive)	Rhodium-ammine perchlorates may be impact-sensitive.
	Mellor **15:** 590 (1946-1947).

RHODIUM TETRABROMIDE $RhBr_4$

Bromine Trifluoride	See BROMINE TRIFLUORIDE plus Potassium Bromide.

RUBBER

Chlorine	See CHLORINE plus Rubber.
Chlorine Trifluoride	See CHLORINE TRIFLUORIDE plus Rubber.
Iodine Monochloride	See IODINE MONOCHLORIDE plus Organic Matter.
Lithium	See LITHIUM plus Organic Matter.

RUBBER (LS-53 and LS-63)

Fluorine	See FLUORINE plus Solid Nonmetals and Oxygen.

RUBIDIUM Rb

Air	Rubidium is spontaneously flammable in air at room temperature if the surface of the metal is clean.
	Mellor **2:** 468 ff. (1946-1947).
Chlorine	See CESIUM plus Chlorine.
Oxygen	Rubidium burns spontaneously in dry oxygen.
	Mellor **2:** 468 (1946-1947).
Phosphorus	See PHOSPHORUS plus Cesium.
Water	At 20¡ C., the heat of reaction is adequate to ignite the hydrogen liberated.
	Mellor **2:** 469 (1946-1947). Bahme, p. 11 (1961).

RUBIDIUM ACETYLIDE RbC≡CH

Arsenic	See ARSENIC plus Rubidium Acetylene Carbide.
Bromine	See BROMINE plus Rubidium Acetylene Carbide.
Chlorine	See BROMINE plus Rubidium Acetylene Carbide.
Cupric Oxide	Cupric oxide is reduced vigorously and with incandescence by rubidium acetylene carbide. *Mellor* **5:** 850 (1946-1947).
Fluorine	See BROMINE plus Rubidium Acetylene Carbide.
Hydrochloric Acid	Rubidium acetylene carbide burns with slightly warm hydrochloric acid or with molten sulfur. *Mellor* **5:** 849 (1946-1947).
Iodine	See BROMINE plus Rubidium Acetylene Carbide.
Lead Oxide	Rubidium acetylene carbide explodes on contact with lead oxide (at 350¡ C.). *Mellor* **5:** 849 (1946-1947).
Manganese Dioxide	Manganese dioxide is reduced by rubidium acetylene carbide at elevated temperatures with incandescence and sometimes explosively. *Mellor* **5:** 850 (1946-1947).
Phosphorus	See PHOSPHORUS plus Rubidium Acetylene Carbide.
Sulfur	See RUBIDIUM ACETYLENE CARBIDE plus Hydrochloric Acid.
Sulfuric Acid	Rubidium acetylene carbide burns with sulfuric acid. *Mellor* **5:** 849 (1946-1947).

RUBIDIUM AZIDE RbN_3

(self-reactive)	Rubidium azide decomposes at 321¡ C. *Mellor* **8, Supp. 2:** 43 (1967).
Carbon Disulfide	See CARBON DISULFIDE plus Azides.

RUBIDIUM CARBIDE Rb_2C_2

Arsenic	See ARSENIC plus Rubidium Carbide.
Arsenic Oxide	If warmed, rubidium carbide will burn with arsenic oxide.
	Mellor **5:** 848 (1946-1947).
Boron	See SILICON plus Rubidium Carbide.
Bromine	See BROMINE plus Rubidium Carbide.
Hydrochloric Acid	Rubidium carbide ignites in contact with hydrochloric acid unless the acid is dilute.
	Mellor **5:** 848 (1946-1947).
Iodine	See IODINE plus Cesium Carbide.
Lead Oxide	If warmed, rubidium carbide will burn with lead oxide.
	Mellor **5:** 848 (1946-1947).
Nitric Acid	A mixture of nitric acid and rubidium carbide will explode.
	Mellor **5:** 848 (1946-1947).
Nitric Oxide	See RUBIDIUM CARBIDE plus Sulfur Dioxide.
Selenium	See SELENIUM plus Rubidium Carbide.
Silicon	See SILICON plus Rubidium Carbide.
Sulfur Dioxide	Rubidium carbide ignites on warming in sulfur dioxide or nitric oxide vapor.
	Mellor **5:** 848 (1946-1947).

RUBIDIUM CHLORIDE RbCl

Bromine Trifluoride	See BROMINE TRIFLUORIDE plus Barium Chloride.

RUBIDIUM HYDRIDE RbH

Acetylene	If moisture is present, rubidium hydride reacts vigorously with acetylene, even at minus 60¡ C.
	Mellor **2:** 483 (1946-1947).

Water	Rubidium hydride ignites on contact with moist air.
	Hurd, pp. 36-37 (1952).

RUBIDIUM NITRIDE Rb_3N

Air	Rubidium nitride burns in air.
	Mellor **8:** 8, 99, 101 (1946-1947).

RUBIDIUM PHOSPHIDE Rb_3P

Water	Rubidium phosphide reacts instantaneously with water or moist air to yield spontaneously flammable phosphine.
	Van Wazer (1958).

RUBIDIUM SILICIDE Rb_2Si_2

Water	See CESIUM SILICIDE plus Water.

RUTHENIUM Ru

Oxygen Difluoride	See IRIDIUM plus Oxygen Difluoride.

RUTHENIUM TETROXIDE RuO_4

Charcoal	Ruthenium tetroxide (gas) in contact with activated charcoal reacted violently.
	Scott (1963).
Phosphorus Tribromide	Ruthenium tetroxide and phosphorus tribromide undergo a vigorous exothermic reaction.
	Mellor **8, Supp. 3:** 521 (1971).

SAMARIUM Sm

Air	See RARE EARTH METALS plus Air.
Halogens	See RARE EARTH METALS plus Halogens.
1,1,2-Trichlorotrifluoroethane	A commercial mixer/mill was demolished and a technician was injured as a result of an explosion which occurred when an attempt was made to grind 20 grams of samarium in approximately 20 cc of 1,1,2-trichlorotrifluoroethane. Subsequent investigation revealed that the explosion was caused by the generation of fresh metal surface in the presence of the chlorinated halocarbon.
	Wischmeyer (1970). *NSC Newsletter, R & D Sec.* (Aug. 1970).

SELENIUM Se

Barium Carbide	A mixture of barium carbide and selenium heated to 150¡ C. becomes incandescent.
	Mellor **5:** 862 (1946-1947).
Bromine Pentafluoride	See ARSENIC plus Bromine Pentafluoride.
Calcium Carbide	Calcium carbide and selenium vapor react with incandescence.
	Mellor **5:** 862 (1946-1947).
Chlorates	A moist mixture of selenium and any chlorates but the alkali chlorates becomes incandescent.
	Mellor **2, Supp. 1:** 583 (1956).
Chlorine Trifluoride	See ANTIMONY plus Chlorine Trifluoride.
Chromium Trioxide	Selenium reacts violently with chromium trioxide.
	Mellor **11:** 233 (1946-1947).
Fluorine	Selenium unites directly with fluorine in the cold, giving off fumes, and finally the selenium ignites.
	Mellor **10:** 747 (1946-1947).
Lithium Carbide	See SULFUR plus Lithium Carbide.
Lithium Silicide	See PHOSPHORUS plus Lithium Silicide.
Nickel	See NICKEL plus Selenium. See also SULFUR plus

	Nickel.
Nitric Acid	Freshly reduced selenium (from selenium dioxide) reacts vigorously with nitric acid. Trace of organic matter probably influenced the reaction.
	Austin, Newman, and Riley, *J. Chem. Soc.*, p. 391 (1938).
Nitrogen Trichloride	See NITROGEN TRICHLORIDE plus Ammonia.
Oxygen	Burning selenium in oxygen has resulted in explosion, probably due to the presence of organic matter.
	Austin, Newman, and Riley, *J. Chem. Soc.*, p. 391 (1938).
Potassium	A mixture of potassium and selenium ignites; sodium does likewise and is attended by vivid incandescence.
	Mellor **10:** 766-7 (1946-1947).
Potassium Bromate	The reaction is violently explosive.
	Mellor **2, Supp. 1:** 763 (1956).
Rubidium Carbide	The carbide burns in selenium vapor.
	Mellor **5:** 848 (1946-1947).
Silver Bromate	The reaction is violently explosive.
	Mellor **2, Supp. 1:** 766 (1956).
Sodium	See SELENIUM plus Potassium.
Strontium Carbide	See SULFUR plus Strontium Carbide.
Thorium Carbide	Selenium vapor attacks heated thorium carbide with incandescence.
	Mellor **5:** 886 (1946-1947).
Uranium	See URANIUM plus Selenium.
Zinc	See ZINC plus Selenium.

SELENIUM CARBIDE SeC_2

Sulfur	See SULFUR plus Thorium Carbide.

SELENIUM IODOPHOSPHIDE $Se_3P_4I_2$

Nitric Acid	These compounds react explosively.
	Mellor **8, Supp. 3:** 247 (1971).

SELENIUM MONOCHLORIDE Se_2Cl_2

Phosphorus	See PHOSPHORUS plus Selenium Monochloride.
Potassium	See POTASSIUM plus Selenium Monochloride.
Potassium Superoxide	Selenium monochloride and potassium superoxide react very violently.
	Mellor **10:** 897 (1946-1947).
Sodium Peroxide	Sodium peroxide reacts violently with the evolution of light when it is treated with selenium monochloride.
	Mellor **10:** 897 (1946-1947.)

SELENIUM OXYCHLORIDE $SeOCl_2$

Phosphorus	See PHOSPHORUS plus Selenium Oxychloride.
Potassium	See POTASSIUM plus Selenium Oxychloride.

SELENIUM OXYFLUORIDE $SeOF_2$

Phosphorus	See PHOSPHORUS plus Selenium Oxyfluoride.

SELENIUM SULFIDE SeS

Silver Oxide	See SILVER OXIDE plus Antimony Trisulfide.

SELENIUM TETRAFLUORIDE SeF_4

Phosphorus	See PHOSPHORUS plus Selenium Tetrafluoride.

SILANE SiH_4

Air	Silicon hydride will ignite in air by slightly raising the temperature or lowering the pressure. *Mellor* **6:** 220 (1946-1947).
Chlorine	See CHLORINE plus Silicon Hydride.

SILANES (SILANE, DISILANE, TRISILANE, etc.)

Air	The first seven to eight members of the series Si_nH_{2n+2} ignite spontaneously in air at room temperature or slightly higher. *Latimer and Hildebrand*, p. 297 (1940). *Z. Anorg. Chemie* **117:** 209. *Mellor* **1:** 376 (1946-1947).

SILICA (SILICON DIOXIDE) SiO_2

Chlorine Trifluoride	See CHLORINE TRIFLUORIDE plus Elements.
Manganese Trifluoride	See MANGANESE TRIFLUORIDE plus Glass.
Oxygen Difluoride	See OXYGEN DIFLUORIDE plus Silica.

SILICATES

Lithium	See LITHIUM plus Carbides.

SILICIDES

(See specific silicides as primary entries or see under other reactants)

SILICOCYN

(See SILICON NITRIDE)

SILICON Si

Alkali Carbonates	When a mixture of amorphous silicon and an alkali carbonate is heated, a vigorous reaction, attended by incandescence, occurs.
	Mellor **6:** 164 (1946-1947).
Aluminum and	A mixture of silicon, aluminum and lead oxide
Lead Oxide	explodes when heated.
	Mellor **7:** 657 (1946-1947).
Calcium	See CALCIUM plus Silicon.
Cesium Carbide	Cesium carbide reacts vigorously when heated with silicon or boron.
	Mellor **5:** 848 (1946-1947).
Chlorine	Silicon burns spontaneously in gaseous chlorine.
	Mellor **2:** 92, 95; **6:** 161; **9:** 626 (1946-1947).
	See ANTIMONY plus Chlorine Trifluoride.
Cobaltic Fluoride	A mixture of silicon powder and cobaltic fluoride glows red on gently warming.
	Mellor **2, Supp. 1:** 64 (1956).
Fluorine	See FLUORINE plus Selenium.
Iodine Pentafluoride	See ARSENIC plus Iodine Pentafluoride.
Manganese Trifluoride	See MANGANESE TRIFLUORIDE plus Glass.
Nitrosyl Fluoride	See BORON plus Nitrosyl Fluoride.
Rubidium Carbide	Rubidium carbide reacts vigorously when heated with silicon or boron.
	Mellor **5:** 848 (1946-1947).
Silver Fluoride	Silicon (powdered) reacts violently with silver fluoride.
	Mellor **3:** 389 (1946-1947).
Sodium-Potassium	The reaction of silicon and sodium-potassium
Alloy	alloy forms sodium silicide, which is spontaneously

	flammable in air.
	Mellor **2, Supp. 2:** 564 (1961).
	See also SODIUM SILICIDE plus Air.

SILICON HYDRIDE

(See SILANE)

SILICON MONOXIDE SiO

Air	Silicon monoxide is spontaneously flammable in air.
	Ellern (1961).

SILICON NITRIDE $(Si_2N_2)_n$

Air	Silicocyn is spontaneously flammable in air.
	Ellern (1961).

SILICON TETRAAZIDE $Si(N_3)_4$

(self-reactive)	Spontaneous explosions have been observed with this compound.
	Mellor **8, Supp. 2:** 50 (1967).
	See BORON TRIAZIDE (self-reactive).

SILICON TETRACHLORIDE $SiCl_4$

Potassium	See POTASSIUM plus Aluminum Bromide.
Sodium	See SODIUM plus Aluminum Bromide.

SILICON TETRAMETHYL

(See TETRAMETHYLSILANE)

SILICYLAMINE $(SiH_3)_3N$

(See TRISILICYLAMINE)

SILOXANE $(OSiH_2)_3$

Air	Siloxane is spontaneously flammable in air.
	Ellern (1961).

SILVER Ag

Acetylene	An insoluble, explosive acetylide is formed with silver.
	Von Schwartz, p. 142 (1918); J. K. Luchs, *Phot. Sci. Eng.* **10**(6): 334-7 (1966).
Ammonia	See GOLD plus Ammonia.
Bromoazide	See ANTIMONY plus Bromoazide.
Chlorine Trifluoride	See ALUMINUM plus Chlorine Trifluoride.
Ethyl Alcohol and	When silver is treated with nitric acid in the
Nitric Acid	presence of ethyl alcohol, silver fulminate may be formed, which can be detonated.
	P. M. Hearbjes and J. P. Howtman, *Chem. Weekblad* **38;** J. K. Luchs, *Phot. Sci. Eng.* **10**(6): 334-7 (1966).
Ethyleneimine	Ethyleneimine forms explosive compounds with silver, hence silver solder should not be used to fabricate equipment for handling ethyleneimine.
	Ethyleneimine.
Hydrogen Peroxide	See IRON plus Hydrogen Peroxide. Finely divided silver and a strong hydrogen peroxide solution may explode.
	Mellor **1:** 936 (1946-1947).
Oxalic Acid	Silver is said to be incompatible with oxalic acid and tartaric acid.
	NavAer. 09-01-505 (November 1, 1956).

Permonosulfuric Acid	See PERMONOSULFURIC ACID plus Manganese Dioxide. See PLATINUM plus Permonosulfuric Acid.
Tartaric Acid	See SILVER plus Oxalic Acid.

SILVER AZIDE AgN_3

(self-reactive)	Silver azide decomposes at 250¡ C. It is explosively unstable.
	Mellor **8, Supp. 2:** 43 (1967).
	Silver azide is shock-sensitive when dry and has a detonation temperature of 250¡ C.
	Photo. Sci. & Eng. **10** (6): 334-337 (1966).
	See also AZIDES.
Bromine	See BROMINE plus Silver Azide.
Iodine	See IODINE plus Silver Azide.

SILVER BROMATE $AgBrO_3$

Sulfur	See SULFUR plus Silver Bromate.
Tellurium	See TELLURIUM plus Silver Bromate.

SILVER BROMIDE AgBr

Potassium	See SODIUM plus Silver Bromide.
Sodium	See SODIUM plus Silver Bromide.

SILVER CHLORATE $AgClO_3$

Sulfur	See SULFUR plus Silver Chlorate.

SILVER CHLORIDE AgCl

Aluminum	See ALUMINUM plus Silver Chloride.

Ammonia	When a solution of silver chloride in aqueous ammonia is exposed to air or to heat, a material, probably silver nitride, is formed that is detonated violently by shock.
	Mellor **3:** 382 (1946-1947); J. K. Luchs, *Phot. Sci. Eng.* **10**(6): 334-7 (1966).
	Kite (1973).
Bromine Trifluoride	See BROMINE TRIFLUORIDE plus Barium Chloride.
Potassium	See SODIUM plus Silver Bromide.
	See POTASSIUM plus Ammonium Bromide.
Sodium	See SODIUM plus Silver Bromide.
Sodium Peroxide and	See SODIUM PEROXIDE plus Silver Chloride
Charcoal	and Charcoal.

SILVER CYANIDE AgCN

Fluorine	See FLUORINE plus Silver Cyanide.

SILVER DIAMIDOTRIOXYPHOSPHORANE

$(AgO)_3P(NHAg)_2$

Sulfuric Acid	Pentasilver trihydroxydiamidophosphate explodes on heating, friction, or treatment with concentrated sulfuric acid.
	J. Am. Chem. Soc. **17:** 275 (1895).
	Tetrasilver trihydroxydiaminophosphate ignites when treated with concentrated sulfuric acid.
	Mellor **8:** 705 (1946-1947).

SILVER FLUORIDE AgF

Boron	See BORON plus Silver Fluoride.
Calcium Hydride	When silver fluoride is ground with calcium hydride, the mass becomes incandescent.

	Mellor **3:** 389 (1946-1947).
Dimethyl Sulfoxide	See DIMETHYL SULFOXIDE plus Silver Fluoride.
Potassium	See SODIUM plus Silver Bromide.
	See POTASSIUM plus Aluminum Bromide.
Silicon	See SILICON plus Silver Fluoride.
Sodium	See SODIUM plus Silver Bromide.
	See SODIUM plus Aluminum Bromide.

SILVER FLUOROACETYLIDE FC≡CAg

(self-reactive)	See FLUOROACETYLENE (self-reactive).

SILVER FULMINATE AgCNO

(self-reactive)	See SILVER CHLORIDE plus Ammonia. Silver fulminate is shock-sensitive when dry and has a detonation temperature of 175¡ C.
	Photo. Sci. & Eng. **10** (6): 334-337 (1966).

SILVER HALIDES

Sodium-Potassium Alloy	See SODIUM-POTASSIUM ALLOY plus Silver Halides.

SILVER IODATE $AgIO_3$

Potassium	See POTASSIUM plus Boric Acid.

SILVER IODIDE AgI

Potassium	See SODIUM plus Silver Bromide.
	See POTASSIUM plus Ammonium Bromide.
Sodium	See SODIUM plus Silver Bromide.

SILVER NITRATE $AgNO_3$

Acetylene	See MERCURY SALTS plus Acetylene.
Acetylene and Ammonium Hydroxide	Silver acetylide is formed on precipitation of an ammoniacal solution of silver nitrate with acetylene. Silver acetylide is highly explosive in the dry state.
	Sprengstoffe, Waffen u. Munitions (1905); J. K. Luchs, *Phot. Sci. Eng.* **10** (6): 334-7 (1966).
Ammonium Hydroxide	When a mixture of 28% ammonium hydroxid and silver nitrate solution was treated with a small amount of sodium hydroxide, black material precipitated. On being stirred the mixture exploded. The cause was formation of the sensitive silver nitride.
	MCA Case History **1554** (1968).
Arsenic	See ARSENIC plus Silver Nitrate.
Calcium Carbide	A highly sensitive explosive is formed by the addition of calcium carbide to a silver nitrate solution.
	Mellor **5:** 881 ff. (1946-1947); J. K. Luchs,
	Phot. Sci. Eng. **10**(6): 334-7 (1966).
Charcoal	A mixture of charcoal and silver nitrate ignites under impact.
	Mellor **3:** 473 (1946-1947).
Chlorine Trifluoride	See CHLORINE TRIFLUORIDE plus Nitric Acid.
Cuprous Acetylide	See CUPROUS ACETYLIDE plus Silver Nitrate.
Ethyl Alcohol	Alcohols should not be mixed with silver nitrate, an explosive fulminate may be formed.
	Bahme, p. 9 (1961): J. K. Luchs, *Phot. Sci. Eng.* **10** (6): 334-7 (1966).
Magnesium	See MAGNESIUM plus Silver Nitrate.
Phosphine	An explosion occurred when purified phosphine was

	passed rapidly into a concentrated solution of silver nitrate.
	Mellor **3:** 471 (1946-1947).
Phosphonium Iodide	See PHOSPHONIUM IODIDE plus Silver Nitrate.
Phosphorus	See PHOSPHORUS plus Silver Nitrate.
Phosphorus Isocyanate	See PHOSPHORUS ISOCYANATE plus Acetaldehyde.
Plastics	In a study to assess potential shipping and storage containers the relative flammability of various plastics in contact with silver nitrate was examined. All plastics tested were shown to undergo propellant-type burning in the presence of silver nitrate under conditions that might be encountered under fire exposure conditions.
	Coffee (1969).
Sulfur	See SULFUR plus Silver Nitrate.

SILVER NITRIDE Ag_3N

(self-reactive)	Silver nitride can be detonated by shock even if wet. Detonation temperature is 100¡ C.
	Photo. Sci. & Eng. **10** (6): 334-337 (1966).
	Dried silver nitride explodes readily, even from a strong flash of light.
	Mellor **8, Supp. 1:** 155 (1964).

SILVER NITRIDOOSMATE $AgOsNO_3$

(self-reactive)	Silver osmiamate detonates violently at 80¡ C or by percussion.
	Mellor **15:** 728 (1946-1947).

SILVER OXALATE AgOCOCOOAg

(self-reactive)	Newly prepared silver oxalate, that had been oven dried for several days at 50¡ C maximum, was placed in a mechanical mortar-and-pestle type grinder. When the motor was turned on, an explosion occurred that seriously

injured two people. Impact detonation was the probable cause of the detonation. Textbooks indicate that silver oxalate is explosive above 150¡ C and that the explosion hazard is moderate when exposed to heat.

BCISC **44** (175): 19 (1973).

Chlorine — See CHLORINE plus Mercuric Oxide.

SILVER OXIDE Ag_2O

Ammonium Hydroxide — An attempt to dissolve silver oxide (prepared 24 hours previously) in ammonium hydroxide in a stainless steel can caused a muffled explosion which distorted the can; numerous subsequent small explosions occurred in the spots of slurry scattered around the room by the initial explosion. Many similar incidents are also reported.

ASESB Expl. Reports **10** (1960); **172** (1964); **190** (1965). *Health & Safety Inf.* **198** (1964); J. K. Luchs, *Phot. Sci. Eng.* **10**(6): 334-7 (1966). *MCA Case History* **976** (1964).

Antimony Trisulfide — Ignition takes place when silver oxide is ground with various metal sulfides, e.g., those of antimony, mercury, selenium.

Mellor **3:** 377 (1946-1947).

Aqueous Ammonia and Ethyl Alcohol — A mixture of silver oxide plus ethyl alcohol and aqueous ammonia forms the very sensitive silver nitride.

Mellor **8:** 101 (1946-1947); J. K. Luchs, *Phot. Sci. Eng.* **10**(6): 334-7 (1966).

Carbon Monoxide — Carbon monoxide reduces silver oxide energetically and considerable heat is generated.

Mellor **3:** 377 (1946-1947).

Magnesium — A mixture of silver oxide and magnesium heated in a sealed tube causes a reaction which proceeds with explosive violence.

Mellor **3:** 378 (1946-1947).

Mercuric Sulfide — See SILVER OXIDE plus Antimony Trisulfide.

Phosphorus	See PHOSPHORUS plus Silver Oxide.
Selenium Sulfide	See SILVER OXIDE plus Antimony Trisulfide.
Sulfur	See SULFUR plus Silver Oxide.

SILVER PERCHLORATE $AgClO_4$

(self-reactive)	Silver perchlorate filter cake exploded while being pulverized in a mortar.
	ACS **146:** 209.
Acetic Acid	Silver perchlorate-acetic acid solvated salt is liable to explode when struck. Shock-sensitive solvated salts are also formed with silver perchlorate and aniline, benzene, chlorobenzene, glycerol, nitrobenzene, pyridine, and toluene.
	Mellor **2, Supp. 1:** 616 (1956).
Aniline	See SILVER PERCHLORATE plus Acetic Acid.
Benzene	An explosion of silver perchlorate crystallized from benzene has been reported. A similar explosion involving ethyl alcohol was cited.
	S. R. Brinkley, *J. Am. Chem. Soc.* **62:** 3524 (1940). *ACS*-**146:** 209.
	See SILVER PERCHLORATE plus Acetic Acid.
Carbon Tetrachloride and Hydrochloric Acid	The reaction of silver perchlorate with carbon tetrachloride in the presence of a small amount of hydrochloric acid produces trichloromethyl perchlorate, which detonates at 40¡ C.
	Kirk and Othmer, *Second Ed.* **5:** 72 (1963).
	Pascal **16:** 316 (1931-1934).
Chlorobenzene	See SILVER PERCHLORATE plus Acetic Acid.
Ethyl Alcohol	See SILVER PERCHLORATE plus Benzene.
Ethylenediamine	A flask exploded while a chemist was adding ethylenediamine drop-wise to silver perchlorate.

	NSC Newsletter, R & D Sec. (Jan. 1970).
Glycerol	See SILVER PERCHLORATE plus Acetic Acid.
Nitrobenzene	See SILVER PERCHLORATE plus Acetic Acid.
Pyridine	See SILVER PERCHLORATE plus Acetic Acid.
Toluene	See SILVER PERCHLORATE plus Acetic Acid.
	Many "hydrocarbon-metal perchlorate" complexes are explosive, for example, the complexes of benzene, toluene, aniline, pyridine, and dioxane.
	Analyst **80:** 13 (1955).

SILVER PERCHLORATE-ACETIC ACID SOLVATED SALT

$AgClO_4CH_3COOH$

(self-reactive)	See SILVER PERCHLORATE plus Acetic Acid.

SILVER PERMANGANATE $AgMnO_4$

Ammonium Hydroxide	Silver permanganate reacts with ammonium hydroxide to form a complex of the formula $[Ag(NH_3)_2]MnO_4$ which is shock sensitive.
	Pascal **16:** 1062 (1931-1934).
Sulfuric Acid (Vapor)	Moist silver permanganate stored for drying in a desiccator over sulfuric acid under vacuum produced a strong explosion.
	Delhez (1967).

SILVER PEROXIDE Ag_2O_2

Polyisobutylene	An explosion occurred during filling of a container with 2 kilograms of silver peroxide containing 1% by weight of polyisobutylene.
	Arbeitsschutz **6:** 248 (1972).

SILVER PHENYL C_6H_5Ag

(See PHENYL SILVER)

SILVER SALTS

Acetylene	See MERCURY SALTS plus Acetylene.
Nitromethane	See COPPER SALTS plus Nitromethane.

SILVER SULFIDE Ag_2S

Iodine Monochloride	See IODINE MONOCHLORIDE plus Cadmium Sulfide.
Potassium Chlorate	See POTASSIUM CHLORATE plus Silver Sulfide.

SODIUM Na

Air	The ignition temperature of sodium in air depends on size of surface exposed: vapor ignites at room temperature; droplets at about 250¡F; an agitated pool at 400¡F.; a calm pool at 500¡-800¡F. In the absence of moisture and hydrogen, the reaction is insignificant below 1000¡F. *Gracie and Droher* (1960). *Mellor* **2, Supp. 2:** 440 (1961).
Aluminum Bromide	A mixture of sodium and any of the following halide compounds produces a strong explosion on impact: aluminum bromide, aluminum chloride, aluminum fluoride, ammonium chlorocuprate, antimony tribromide, antimony trichloride, antimony triiodide, arsenic trichloride, arsenic triiodide, bismuth tribromide, bismuth trichloride, bismuth triiodide, boron tribromide, cupric chloride, ferrous chloride, iodine monobromide, manganous chloride, mercuric bromide, mercuric chloride, mercuric fluoride, mercuric iodide, mercurous chloride, silicon tetrachloride, silver fluoride, stannic chloride, stannic iodide (with sulfur), stannous chloride, sulfur dibromide, thallous bromide, vanadium pentachloride, and zinc bromide. *Mellor* **2, Supp. 2:** 497 (1961).

Aluminum Chloride	See SODIUM plus Aluminum Bromide.
Aluminum Fluoride	See SODIUM plus Aluminum Bromide.
Ammonium Chlorocuprate	See SODIUM plus Aluminum Bromide.
Ammonium Nitrate	Sodium and ammonium nitrate react through a series of reductions to form a yellow explosive substance believed to be disodium nitrite.
	Mellor **8: Supp. I, Part I,** p. 546 (1964).
Antimony Tribromide	See SODIUM plus Aluminum Bromide.
Antimony Trichloride	See SODIUM plus Aluminum Bromide.
Antimony Triiodide	See SODIUM plus Aluminum Bromide.
Arsenic Trichloride	See SODIUM plus Aluminum Bromide.
Arsenic Triiodide	See SODIUM plus Aluminum Bromide.
Bismuth Tribromide	See SODIUM plus Aluminum Bromide.
Bismuth Trichloride	See SODIUM plus Aluminum Bromide.
Bismuth Triiodide	See SODIUM plus Aluminum Bromide.
Bismuth Trioxide	Sodium reduces the heated trioxide to the metal and the reaction is accompanied by incandescence.
	Mellor **9:** 649 (1946-1947).
Boron Tribromide	See SODIUM plus Aluminum Bromide.
Bromine	Finely divided sodium reacts with bromine with luminescence. The system, solid sodium plus liquid bromine, requires a light mechanical shock to explode it.
	Mellor, **Supp. II, Part I:** 714 (1956). H. Staudinger, *Z. Elektrochem.* **31:** 549-52 (1925).
	See BROMINE plus Potassium.
Bromoazide	See ANTIMONY plus Bromoazide.
Carbon Dioxide	Molten sodium can be plunged into a carbon dioxide atmosphere without causing a vigorous reaction. But sodium manufacturers warn against using carbon dioxide on fires, because molten sodium burns with increasing

	vigor as the temperature is elevated. Small sodium fires can, however, be covered with solvent, like kerosine, and the resultant kerosine fire can be attacked with carbon dioxide.
	H. N. Gilbert, *Chem. Eng. News* **26:** 2604 (1948). *Metallic Sodium,* p. 19 (1952). *"Ethyl" Sodium,* p. 10 (1954). *Sodium, Plant Scale,* p. 38 (1956).
	An explosive reaction occurs when dry ice and solid sodium are brought together by impact.
	Mellor **2, Supp. 2:** 468 (1961).
Carbon Monoxide and Ammonia	The reaction of sodium and carbon monoxide in liquid ammonia forms sodium carbonyl, which explodes when heated in air.
	Mellor **2, Supp. 2:** 467 (1961).
	See also SODIUM CARBONYL plus Air.
Carbon Tetrachloride	Carbon tetrachloride reacts violently with hot sodium.
	Bahme, p. 12 (1961). *Ellern,* p. 43 (1968).
	See SODIUM plus Carbon Dioxide.
	See SODIUM plus Cobaltous Bromide.
Chlorinated Hydrocarbons	Sodium forms explosive mixtures with chlorinated hydrocarbons.
	H. N. Gilbert, *Chem. Eng. News* **26:** 2604 (1948).
Chlorine	Cold sodium is spontaneously flammable in moist chlorine.
	Mellor **2:** 95, 469 (1946-1947).
	The vapors of sodium and chlorine react with a luminous flame.
	Mellor **2, Supp. 1:** 380 (1956).
Chlorine Trifluoride	See CALCIUM plus Chlorine Trifluoride.
Chloroform	The system, sodium plus chloroform, is shock-sensitive, producing a fairly strong explosion.

	H. Staudinger, *Z. Elektrochem.* **31:** 549-52 (1925).
	See LITHIUM plus Chloroform.
	See POTASSIUM plus Chloroform.
Chromium Tetrachloride	A mixture of sodium and chromium tetrachloride creates a very violent explosion on impact.
	Mellor **2, Supp. 2:** 497 (1961).
Chromium Trioxide	Sodium or potassium reacts with chromium trioxide with incandescence.
	Mellor **11:** 237 (1946-1947).
Cobaltous Bromide	A very violent explosion results when a mixture of sodium and any of the following is struck with a hammer: cobaltous bromide, carbon tetrachloride, cobaltous chloride, ferric bromide, ferric chloride, ferrous bromide, ferrous iodide, phosphorus pentachloride, phosphorus tribromide, sulfur dichloride.
	Mellor **2, Supp. 2:** 497 (1961).
Cobaltous Chloride	See SODIUM plus Cobaltous Bromide.
Cupric Chloride	See SODIUM plus Aluminum Bromide.
Cupric Oxide	Cupric oxide is reduced when heated with sodium. The reaction proceeds with vivid incandescence.
	Mellor **3:** 138 (1946-1947).
1,2-Dichloroethylene	The addition of sodium, caustic or caustic solutions to 1,2-dichloroethylene or to trichloroethylene may form monochloroacetylene or dichloroacetylene, respectively. The addition of sodium or caustic to tetrachloroethane may form either of the chloroacetylenes, both of which are spontaneously flammable in air. Avoid the contact of the above chlorohydrocarbons with sodium or caustic except under carefully controlled experimental conditions.
	NAVWEPS OP **3237,** p. 28 (1964). *Fire and Accident Prev.* **42** (1956).
Dichloromethane	Sodium and other alkali metals form sensitive explosive mixtures with chloroform, dichloromethane, and methyl chloride.

	H. Staudinger, *Z. Elektrochem.* **31:** 549 (1925).
Ferric Bromide	See SODIUM plus Cobaltous Bromide.
Ferric Chloride	See SODIUM plus Cobaltous Bromide.
Ferrous Bromide	See SODIUM plus Cobaltous Bromide.
Ferrous Chloride	See SODIUM plus Aluminum Bromide.
Ferrous Iodide	See SODIUM plus Cobaltous Bromide.
Fluorine	Sodium burns spontaneously in fluorine.
	Mellor **2:** 469 (1946-1947).
	Mellor **2, Supp. 2:** 450 (1961).
Hydrazine Hydrate	Hydrazine hydrate and sodium develop much heat with the liberation of hydrogen and ammonia. If hydrazine hydrate is added drop by drop to finely granulated sodium, suspended in ether, and the mixture is heated, a white substance is formed, which explodes in air.
	Mellor **8:** 316 (1946-1947).
Hydrochloric Acid	Sodium explodes on contact with hydrochloric acid.
	Mellor **2:** 469 (1946-1947).
Hydrofluoric Acid	An aqueous solution of hydrofluoric acid reacts with sodium with explosive violence.
	Mellor **2:** 469 (1946-1947).
Hydrogen Chloride	Sodium reacts very vigorously with gaseous hydrogen chloride.
	Mellor **2, Supp. 2:** 452 (1961).
Hydrogen Peroxide	See LEAD DIOXIDE plus Hydrogen Peroxide.
Hydrogen Sulfide	A very rapid reaction results when moist gaseous hydrogen sulfide contacts sodium.
	Mellor **2, Supp. 2:** 456 (1961).
Hydroxylamine	Sodium and hydroxylamine (in an ether solution) form sodium hydroxylamine, which is spontaneously flammable in air.
	Mellor **8:** 290 (1946-1947).

Iodine	See IODINE plus Lithium.
Iodine Monobromide	A mixture of sodium and iodine monobromide explodes when struck with a hammer. *Mellor* **2, Supp. 2:** 452 (1961). See also SODIUM plus Aluminum Bromide.
Iodine Monochloride	See POTASSIUM plus Iodine Monochloride. The reaction of sodium and iodine monochloride is vigorous when both materials are molten. *Mellor* **2, Supp. 2:** 451 (1961).
Iodine Pentafluoride	A mixture of iodine pentafluoride and potassium or sodium (molten) will explode. *Mellor* **2:** 114 (1946-1947).
Lead Oxide	Sodium, reduced to a fine state of subdivision, when mixed with lead oxide ignites spontaneously. *Mellor* **7:** 658 (1946-1947).
Maleic Anhydride	See ALKALI METALS plus Maleic Anhydride.
Manganous Chloride	See SODIUM plus Aluminum Bromide.
Mercuric Bromide	See SODIUM plus Aluminum Bromide.
Mercuric Chloride	See SODIUM plus Aluminum Bromide.
Mercuric Fluoride	See SODIUM plus Aluminum Bromide.
Mercuric Iodide	See SODIUM plus Aluminum Bromide.
Mercurous Chloride	See SODIUM plus Aluminum Bromide.
Mercurous Oxide	Molten sodium or potassium decomposes mercurous oxide with a slight explosion. J. B. Senderens, *Bull. Soc. Chim.* (3) **6:** 802 (1891).
Methyl Chloride	Sodium and other alkali metals react explosively with methyl chloride. H. Staudinger, *Z. Elektrochem.* **31:**549-52 (1925).
Molybdenum Trioxide	Molybdenum trioxide is reduced by either potassium or sodium with incandescence.

	Z. Anorg. Chemie **190:** 270 (1930).
Monoammonium Phosphate	An explosive reaction occurred when monoammonium phosphate was used to extinguish a sodium fire. No reactions were experienced when sodium bicarbonate or potassium bicarbonate was used in a sodium fire.
	Bohling (1971).
Nitric Acid	Sodium ignites spontaneously in contact with nitric acid of specific gravity exceeding 1.056.
	Mellor **2:** 470 (1946-1947).
	Mellor **2, Supp. 2:** 452 (1961).
Nitrogen Peroxide	Gaseous sodium reacts with the vapors of nitrogen peroxide and nitrous oxide with marked luminescence at 260¡ C.
	Mellor **2, Supp. 2:** 463 (1961).
Nitrosyl Fluoride	The reaction between nitrosyl fluoride and sodium forms sodium fluoride with incandescence.
	Z. Anorg. Chemie **47:** 190 (1905).
Nitrous Oxide	See SODIUM plus Nitrogen Peroxide.
Phosgene	Vapors of sodium and phosgene react with luminescence at about 260¡ C.
	Mellor **2, Supp. 2:** 470 (1961).
Phosphorus	See PHOSPHORUS plus Cesium.
Phosphorus Pentachloride	Molten sodium may ignite or explode when in contact with phosphorus pentachloride.
	Baudrimant.
	See also SODIUM plus Cobaltous Bromide.
Phosphorus Pentoxide	See POTASSIUM plus Phosphorus Pentoxide.
Phosphorus Tribromide	Metallic sodium merely floats on liquid phosphorus tribromide, losing its metallic lustre; but, if a little water is sprinkled on the surface, there is a violent explosion.

	Z. Anorg. Chemie **41:** 276 (1904).
	See SODIUM plus Cobaltous Bromide.
Phosphorus Trichloride	Phosphorus trichloride explodes at the fusion temperature of sodium.
	Mellor **2:** 470 (1946-1947).
	See also SODIUM plus Phosphoryl Chloride.
Phosphoryl Chloride	Gaseous sodium reacts with the vapors of phosphoryl chloride and phosphorus trichloride with luminescence at 270¡ C.
	Mellor **2, Supp. 2:** 463 (1961).
Potassium Oxides	See POTASSIUM plus Air.
Potassium Ozonide	Sodium in contact with either potassium ozonide or potassium superoxide produces an explosive reaction.
	Mellor **2, Supp. 3:** 1577 (1963).
Potassium Superoxide	See SODIUM plus Potassium Ozonide.
Selenium	Potassium reacts with selenium and is attended by burning; sodium does likewise and is attended by vivid incandescence.
	Mellor **10:** 766-7 (1946-1947).
	The reaction of sodium and selenium is luminescent above 300¡ C at low pressure.
	Mellor **2, Supp. 2:** 455 (1961).
Silicon Tetrachloride	See SODIUM plus Aluminum Bromide.
Silver Bromide	Silver bromide, silver chloride, silver fluoride, and silver iodide form impact-sensitive systems with sodium and other alkali metals.
	H. Staudinger, *Z. Elektrochem.* **31:** 549-52 (1925).
Silver Chloride	See SODIUM plus Silver Bromide.
Silver Fluoride	See SODIUM plus Silver Bromide.
	See SODIUM plus Aluminum Bromide.

Silver Iodide	See SODIUM plus Silver Bromide.
Sodium Peroxide	The reduction of sodium peroxide by molten sodium at 500¡ C is a very vigorous reaction.
	U.S. AEC Document UCRL-**1864:** 2-23 (1954).
Stannic Chloride	See SODIUM plus Aluminum Bromide.
Stannic Iodide and Sulfur	See SODIUM plus Aluminum Bromide.
Stannic Oxide	Stannic oxide is reduced by sodium or potassium with incandescence.
	Mellor **7:** 401, 418 (1946-1947).
Stannous Chloride	See SODIUM plus Aluminum Bromide.
Sulfur	When sulfur is rubbed with sodium, the reaction proceeds with explosive violence.
	Mellor **2:** 469 (1946-1947).
	Mellor **2, Supp. 2:** 455 (1961).
Sulfur Dibromide	See SODIUM plus Aluminum Bromide.
Sulfur Dichloride	A mixture of sodium and sulfur dichloride explodes when struck with a hammer.
	Mellor **2, Supp. 2:** 460 (1961).
Sulfur Dioxide	Sulfur dioxide reacts violently with sodium near the melting point.
	H. N. Gilbert, *Chem. Eng. News* **26:** 2604 (1948).
	The reaction of sodium and sulfur dioxide is almost as vigorous as that between sodium and water.
	Mellor **2, Supp. 2:** 458 (1961).
Sulfuric Acid	A dilute aqueous solution of sulfuric acid reacts with sodium with explosive violence.
	Mellor **2:** 470 (1946-1947).
	Mellor **2, Supp. 2:** 453 (1961).
Tellurium	A vigorous reaction results when liquid tellurium is poured

	over solid sodium.
	Mellor **2, Supp. 2:** 455 (1961).
Tetrachloroethane	Tetrachloroethane may explode with potassium or sodium. See also SODIUM plus 1,2-Dichloroethylene.
	Chem. Safety Data Sheet **SD-34** (1949).
Thallous Bromide	See SODIUM plus Aluminum Bromide.
Thiophosphoryl	When thiophosphoryl fluoride is passed over a
Fluoride	metal such as heated sodium or potassium, the metal ignites. The residual mass, when treated with water, gives off spontaneously flammable phosphine.
	Mellor **8:** 1072 (1946-1947).
Trichloroethylene	See SODIUM plus 1,2-Dichloroethylene.
Vanadium	See SODIUM plus Aluminum Bromide.
Pentachloride	
Vanadyl Chloride	Sodium and vanadyl chloride react violently when heated to 180¡ C.
	Mellor **2, Supp. 2:** 496 (1961).
Water	At 40¡C. the heat of reaction is adequate to ignite the hydrogen liberated.
	Mellor **2:** 469 (1946-1947).
	See SODIUM plus Carbon Dioxide.
Zinc Bromide	See SODIUM plus Aluminum Bromide.

SODIUM ACETATE CH_3COONa

Fluorine	See FLUORINE plus Sodium Acetate.
Potassium Nitrate	See POTASSIUM NITRATE plus Sodium Acetate.

SODIUM ACETOACETIC ESTER $C_2H_5OCOCH{=}CO(Na)CH_3$

2-Iodo-3,	See 2-IODO-3, 5-DINITROBIPHENYL plus

5-Dinitrobiphenyl	Ethyl Sodio-Acetoacetate.

SODIUM ACETYLIDE NaC≡CH

Bromine	See BROMINE plus Sodium Acetylene Carbide.
Chlorine	See BROMINE plus Sodium Acetylene Carbide.

SODIUM ACI-NITROMETHYLIDE $NaON(CH_2)O$

Water	Sodium or potassium salts of nitromethane exploded when the dry salt was moistened with a little water.
	Chem. Eng. News **28:** 1473 (1950).

SODIUM ALUMINUM HYDRIDE

(See SODIUM TETRAHYDROALUMINATE)

SODIUM AMIDE $NaNH_2$

Chromic Anhydride	When these solids are ground together, a vigorous reaction results.
	Mellor **11:** 234 (1946-1947).
1,1-Diethoxy-2-chloroethane	The reaction in the presence of ammonia produces sodium ethoxyacetylide, which is extremely pyrophoric.
	Rutledge, p. 35 (1968).
Potassium Chlorate	See POTASSIUM CHLORATE plus Sodium Amide.
Water	Sodium amide reacts violently with water and frequently bursts into flame.
	F. W. Bergstrom and W. C. Fernelius, *Chem. Reviews* **12:** 61 (1933).

SODIUM AZIDE NaN_3

(self-reactive)	Sodium azide decomposes at 275¡ C.

	Mellor **8, Supp. 2:** 43 (1967).
Benzoyl Chloride and Potassium Hydroxide	The mixture of sodium azide and benzoyl chloride reacts spontaneously with evolution of heat in a potassium hydroxide solution.
	Mellor **8, Supp. 2:** 55 (1967).
Bromine	See BROMINE plus Silver Azide.
Carbon Disulfide	See CARBON DISULFIDE plus Azides.
Chromyl Chloride	The reaction of sodium azide and chromyl chloride is an explosive one.
	Mellor **8, Supp. 2:** 36 (1967).
Copper	A solution of sodium azide in copper pipe with lead joints formed copper azide and lead azide, both detonating compounds.
	Klotz (1973).
Dibromomalononitrile	these materials react to produce a product that is extremely sensitive to light shock.
	MCA Case History **820** (1962). *ASESB Expl. Report* **89** (1962).
Dimethyl Sulfate	During preparation of methyl azide from reaction of these two chemicals, a violent explosion occurred. Apparently the pH was allowed to fall below 5. At this acidity hydrazoic acid, a powerful explosive, readily forms.
	MCA Case History **887** (1963).
Lead	See SODIUM AZIDE plus Copper.
Nitric Acid	The reaction of sodium azide and strong nitric acid is energetic.
	Mellor **8, Supp. 2:** 315 (1967).

SODIUM BENZYL $C_6H_5CH_2Na$

(See BENZYL SODIUM)

SODIUM BICARBONATE $NaHCO_3$

Monoammonium Phosphate	A self-propagating reaction can occur when either sodium bicarbonate- or potassium bicarbonate-based dry chemical extinguishing agent is mixed with monoammonium phosphate dry chemical extinguishing agent. Moisture will accelerate the reaction. Products are water, ammonia, carbon dioxide and various solid substances. In a fire extinguisher the pressure developed will blow out the valve.
	Fire J. **60** (1):49 (1966).
Sodium-Potassium Alloy	See SODIUM-POTASSIUM ALLOY plus Water.

SODIUM BISULFIDE NaHS

m-Chloroaniline Diazonium Salt	See SODIUM SULFIDE plus Diazonium and Diazonium Chloride Salts.
4-Chloro-o-toluidine Diazonium Chloride	See SODIUM SULFIDE plus Diazonium and Diazonium Chloride Salts.
o-Nitroaniline Diazonium Salt	See SODIUM SULFIDE plus Diazonium and Diazonium Chloride Salts.
Diazonium Salts	See DIAZONIUM SALTS plus Thiophenates.

SODIUM BORINATE $NaBH_2O$

(self-reactive)	Sodium hypoborate is a stronger, more violent reducing agent than sodium hypophosphite.
	Mellor **5:** 37 (1946-1947).

SODIUM BROMATE $NaBrO_3$

Aluminum	See ALUMINUM plus Bromates.

Arsenic	See ARSENIC plus Bromates.
Carbon	See CARBON plus Bromates.
Copper	See COPPER plus Bromates.
Lubricant	See BROMATES plus Organic Matter.
Metal Sulfides	See METAL SULFIDES plus Bromates.
Organic Matter	See BROMATES plus Organic Matter.
Phosphorus	See PHOSPHORUS plus Bromates.
Sulfur	See SULFUR plus Bromates.

SODIUM BROMIDE NaBr

Bromine Trifluoride	See BROMINE TRIFLUORIDE plus Potassium Bromide.

SODIUM CARBIDE Na_2C_2

Aluminum	See MERCURY plus Sodium Carbide.
Bromine	See BROMINE plus Sodium Carbide.
Carbon Dioxide	Sodium carbide reacts with incandescence when placed in carbon dioxide, chlorine, or sulfur dioxide.
	Von Schwartz, p. 328 (1918).
	Sodium carbide ignites on warming in carbon dioxide.
	Mellor **5:** 848 (1946-1947).
Chlorine	See SODIUM CARBIDE plus Carbon Dioxide.
	See CHLORINE plus Sodium Carbide.
Iron	See MERCURY plus Sodium Carbide.
Lead	See MERCURY plus Sodium Carbide.
Mercury	See MERCURY plus Sodium Carbide.
Nitrogen Pentoxide	Nitrogen pentoxide attacks sodium carbide with incandescence at 150¡ C.
	Mellor **5:** 848-50 (1946-1947).

Phosphorus	See PHOSPHORUS plus Sodium Carbide.
Sulfur Dioxide	See SODIUM CARBIDE plus Carbon Dioxide.
Water	See BROMINE plus Sodium Carbide.
	An explosion of sodium carbide can occur in water if a large excess of carbide is present.
	Mellor **5:** 848 (1946-1947).

SODIUM CARBONATE Na_2CO_3

Aluminum	See ALUMINUM plus Sodium Carbonate.
Fluorine	See FLUORINE plus Carbonates.
Phosphorus Pentoxide	The anhydrous reaction of sodium carbonate and phosphorus pentoxide, initiated by local heating, can generate relatively high temperatures.
	Mellor **8, Supp. 3:** 406 (1971).
Sulfuric Acid	Stratified concentrated sulfuric acid in a reaction tank was suddenly contacted by alkali wash. The violent ensuing reaction caused a geyser of material, propelled by carbon dioxide and steam, to shoot from the manhole of the tank.
	MCA Case History **888** (1963).

SODIUM CARBONYL NaCOCONa

Air	Sodium carbonyl or potassium carbonyl explodes on contact with air or water.
	Mellor **5:** 951-54 (1946-1947).
	See also SODIUM plus Carbon Monoxide and Ammonia.
Water	See SODIUM CARBONYL plus Air.

SODIUM CHLORATE $NaClO_3$

(See also CHLORATES)

Aluminum	See ALUMINUM plus Bromates.

Ammonium	A bulk cargo of sodium chlorate became hot
Thiosulfate	while being transported in a tank that had previously contained ammonium thiosulfate. Under controlled laboratory conditions, a small quantity of ammonium thiosulfate in sodium chlorate could be made to decompose explosively.
	MCA Case History **2019** (April 1974).
Antimony Sulfide	See CHLORATES plus Antimony Sulfide.
Arsenic	See ARSENIC plus Bromates.
Arsenic Trioxide	The two chemicals form a spontaneously flammable mixture.
	Ellern, p. 51 (1968).
Carbon	See CARBON plus Bromates.
Charcoal	See CHLORATES plus Organic Matter.
Copper	See COPPER plus Bromates.
Manganese Dioxide	See CHLORATES plus Manganese Dioxide.
Metal Sulfides	See METAL SULFIDES plus Bromates.
Organic Acids (Dibasic)	See CHLORATES plus Organic Acids (Dibasic).
Organic Matter	Mixtures containing more than 10 per cent sodium chlorate are sufficiently combustible to be hazardous at low relative humidity. Mixtures of sodium chlorate with organic material such as charcoal, sugar, flour or shellac may be ignited by friction or shock.
	Chem. Safety Data Sheet **SD-42** (1951). W. H. Cook, *Can. J. Research* **8:** 509-44 (1933).
	See CHLORATES plus Organic Matter.
Phosphorus	See PHOSPHORUS plus Bromates.
Potassium Cyanide	See CHLORATES plus Antimony Sulfide. See POTASSIUM CYANIDE plus Sodium Chlorate. See CHLORATES plus Potassium Cyanide.
Sulfur	See SULFUR plus Chlorates. See SULFUR plus Bromates.
Sulfuric Acid	Chlorates when brought in contact with sulfuric acid are

	likely to cause fire or explosions.
	Bahme, p. 29 (1961).
Thiocyanates	See CHLORATES plus Antimony Sulfide.
	See THIOCYANATES plus Chlorates.
Zinc	See ZINC plus Chlorates.

SODIUM CHLORIDE NaCl

Bromine Trifluoride	See BROMINE TRIFLUORIDE plus Potassium Bromide.
Lithium	See LITHIUM plus Sodium Chloride.

SODIUM CHLORITE $NaClO_2$

(self-reactive)	The trihydrate crystals of sodium chlorite explode on percussion.
	Mellor **2, Supp. 1:** 573 (1956).
Acids	Sodium chlorite and acids react with rapid evolution of spontaneously explosive chlorine dioxide gas. If heated above 347¡ F., the reaction produces adequate heat to become self-sustaining.
	Diox Process (1949).
Organic Matter	A mixture of organic matter and sodium chlorite can be extremely sensitive to heat, impact, or friction.
	Diox Process (1949).
Oxalic Acid	A bleach mix was prepared by placing weighed quantities of the two chemicals in a stainless steel beaker. As water was being added, the mixture fizzed a moment, then exploded. Toxic chlorine dioxide gas was evolved.
	MCA Case History **839** (1962).
Phosphorus	See PHOSPHORUS plus Sodium Chlorite.
Sulfur	See SULFUR plus Sodium Chlorite.

SODIUM CYANIDE NaCN

Nitrates	See NITRATES plus Cyanides.
Nitrites	See CYANIDES plus Chlorates.

SODIUM DICHROMATE $Na_2Cr_2O_7$

Hydrazine	See POTASSIUM DICHROMATE plus Hydrazine.

SODIUM DIOXIDE

(See SODIUM PEROXIDE)

SODIUM ETHOXYACETYLIDE $NaC{\equiv}COC_2H_5$

(self-reactive)	See SODIUM AMIDE plus 1,1-Diethoxy-2-chloroethane.

SODIUM ETHYL C_2H_5Na

(See ETHYL SODIUM)

SODIUM HYDRAZIDE $NaNHNH_2$

Air	Addition of air, or alcohol, or moisture to sodium hydrazide can produce an explosion. *Mellor* **8:** 336 (1946-1947).
Alcohol	See SODIUM HYDRAZIDE plus Air.
Moisture	See SODIUM HYDRAZIDE plus Air.

SODIUM HYDRIDE NaH

Acetylene	If moisture is present, the reaction between sodium hydride and acetylene is vigorous even at minus 60¡ C. *Mellor* **2:** 483 (1946-1947).
Air	Sodium hydride is spontaneously flammable in air if

	moistened with water.
	Von Schwartz, p. 328 (1918).
Chlorine	See CHLORINE plus Sodium Hydride.
Dimethyl Sulfoxide	See DIMETHYL SULFOXIDE plus Sodium Hydride.
Fluorine	See CHLORINE plus Sodium Hydride.
Iodine	See IODINE plus Sodium Hydride.
Oxygen	See OXYGEN plus Sodium Hydride.
Sulfur	See SULFUR plus Sodium Hydride.
Water	Sodium hydride that was accidentally spilled from a polyethylene bag ignited spontaneously on contact with moisture.
	MCA Case History **1587** (1969).

SODIUM HYDROSULFITE $Na_2S_2O_4$

Water	Moist sodium hydrosulfite is likely to ignite upon drying.
	Bahme, p. 95 (1961).

SODIUM HYDROXIDE NaOH

Acetaldehyde	See ACETALDEHYDE plus Sodium Hydroxide.
Acetic Acid	Mixing sodium hydroxide and glacial acetic acid in a closed container caused the temperature and pressure to increase.
	Flynn and Rossow (1970). See Note under complete reference.
Acetic Anhydride	Mixing sodium hydroxide and acetic anhydride in a closed container caused the temperature and pressure to increase.
	Flynn and Rossow (1970). See Note under complete reference.
Acrolein	An extremely violent polymerization reaction of acrolein results from contact with alkaline materials such as sodium

	hydroxide, potassium hydroxide, ammonia, and amines.
	Chem. Safety Data Sheet **SD-85** (1961).
	Mixing sodium hydroxide and acrolein in a closed container caused the temperature and pressure to increase.
	Flynn and Rossow (1970). See Note under complete reference.
Acrylonitrile	Violent polymerization takes place in the presence of concentrated caustic (e.g., sodium hydroxide, potassium hydroxide).
	Haz. Chem. Data (1966).
Allyl Alcohol	See ALLYL ALCOHOL plus Sodium Hydroxide.
Allyl Chloride	In contact with dry sodium hydroxide, hydrolysis may take place producing allyl alcohol.
	Ventrone (1971).
Aluminum	See ALUMINUM plus Sodium Hydroxide.
Chlorine Trifluoride	See CHLORINE TRIFLUORIDE plus Nitric Acid.
Chloroform and	When 1 gram of sodium hydroxide was added
Methyl Alcohol	to a mixture of 1 ml methanol and 1 ml chloroform, an exothermic reaction occurred. Potassium hydroxide and other alkalies may replace sodium hydroxide as a reactant.
	J. S. Snyder, *Fawcett and Wood*, p. 302 (1965).
Chlorohydrin	Mixing sodium hydroxide and chlorohydrin in a closed container caused the temperature and pressure to increase.
	Flynn and Rossow (1970). See Note under complete reference.
Chloronitrotoluenes	Inadvertent contamination of mixed chloronitrotoluenes by sodium hydroxide in a feed line caused an exothermic reaction with runaway pressure build-up and eventual explosion of the processing apparatus.
	Queener (1966). *ASESB Expl. Report* **130** (1963).
Chlorosulfonic Acid	Mixing sodium hydroxide and chlorosulfonic acid in a closed container caused the temperature and pressure to increase.

	Flynn and Rossow (1970). See Note under complete reference.
1,2-Dichloroethylene	See SODIUM plus 1,2-Dichloroethylene.
Ethylene Cyanohydrin	Mixing sodium hydroxide and ethylene cyanohydrin in a closed container caused the temperature and pressure to increase.
	Flynn and Rossow (1970). See Note under complete reference.
Glyoxal	Mixing sodium hydroxide and glyoxal in a closed container caused the temperature and pressure to increase.
	Flynn and Rossow (1970). See Note under complete reference.
Hydrochloric Acid	Mixing sodium hydroxide and 36% hydrochloric acid in a closed container caused the temperature and pressure to increase.
	Flynn and Rossow (1970). See Note under complete reference.
Hydrofluoric Acid	Mixing sodium hydroxide and 48.7% hydrofluoric acid in a closed container caused the temperature and pressure to increase.
	Flynn and Rossow (1970). See Note under complete reference.
Hydroquinone	Crude hydroquinone was pumped into a sodium hydroxide storage tank by mistake. The hydroquinone liquor at 85¡C decomposed rapidly in the presence of the sodium hydroxide resulting in overflow of the tank and evolution of a considerable amount of heat.
	Wischmeyer (1969).
Maleic Anhydride	The presence of a residue of weak sodium hydroxide solution in a pressure vessel caused maleic anhydride to decompose in a runaway explosive reaction.
	Chem. Haz. Info. Series **C-71:** 5 (1960).
	Alkali and other alkaline earth compounds such as potassium, lithium, calcium, barium and magnesium compounds, as well as amines and other nitrogen

	compounds will cause explosive decomposition of maleic anhydride.
	MCA Case History **622** *and Suppl. to* **622** (1960).
	Vogler, Cecil, and Koerner, *J. Chem. Eng. Data* **8** (4): 620-3 (1963).
Nitric Acid	Mixing sodium hydroxide and 70% nitric acid in a closed container caused the temperature and pressure to increase.
	Flynn and Rossow (1970). See Note under complete reference.
Nitroethane	See CALCIUM HYDROXIDE plus Nitroethane.
Nitromethane	See CALCIUM HYDROXIDE plus Nitroethane.
Nitroparaffins	See CALCIUM HYDROXIDE plus Nitroethane.
Nitropropane	See CALCIUM HYDROXIDE plus Nitroethane.
Oleum	Mixing sodium hydroxide and oleum in a closed container caused the temperature and pressure to increase.
	Flynn and Rossow (1970). See Note under complete reference.
Pentol (3-Methyl-2-	Pentol, being fractionated under high vacuum,
Penten-4-yn-1-ol)	was accidentally contacted by caustic cleaning solution and a violent explosion resulted.
	MCA Case History **363.** *Chem. Process (Chicago)* **27:** 111 (1964).
Phosphorus	See PHOSPHORUS plus Alkaline Hydroxide.
Phosphorus Pentoxide	See CALCIUM OXIDE plus Phosphorus Pentoxide.
Propiolactone (beta-)	Mixing sodium hydroxide and propiolactone (beta-) in a closed container caused the temperature and pressure to increase.
	Flynn and Rossow (1970). See Note under complete reference.
Sulfuric Acid	Mixing sodium hydroxide and 96% sulfuric acid in a closed container caused the temperature and pressure to increase.
	Flynn and Rossow (1970). See Note under complete

	reference.
Tetrachlorobenzene and Methyl Alcohol	In the manufacturing of the sodium salt of trichlorophenol, sodium hydroxide, methyl alcohol and tetrachlorobenzene were heated. During the heating process, the pressure suddenly increased rapidly and an explosion occurred.
	MCA Guide for Safety, Appendix 3 (1972).
Tetrahydrofuran	See TETRAHYDROFURAN plus Potassium Hydroxide.
Trichloroethylene	When heated, trichloroethylene and sodium hydroxide or potassium hydroxide form explosive mixtures of dichloroacetylene.
	Chem. Safety Data Sheet **SD-14** (1956).
	The presence of alkylamines as a stabilizer in commercial trichloroethylene furnishes a catalyst that accelerates this reaction.
	MCA Case History **495.** *Fire and Accident Prev.* **42** (June 8, 1956).
	A pail of trichloroethylene dumped into a tank of caustic caused a fireball and eruption of the contents.
	MCA Case History **1065** (1965).
	See SODIUM plus 1,2-Dichloroethylene.
Water	Sodium hydroxide in contact with water may generate enough heat to ignite adjacent combustible materials.
	Haz. Chem. Data (1966).

SODIUM HYDROXYLAMINE NH_2ONa

Air	Sodium hydroxylamine is spontaneously flammable in air.
	Mellor **8:** 290 (1946-1947).

SODIUM HYPOBROMITE NaOBr

Acetone	See ACETONE plus Sodium Hypobromite.
Cupric Salts	Solutions of sodium hypobromite are decomposed by powerful catalytic action of cupric ions, even as impurities.
	Mellor **2, Supp. 1:** 751 (1956).

SODIUM HYPOCHLORITE NaOCl

(See also HYPOCHLORITES)

(self-reactive)	Anhydrous sodium hypochlorite is very explosive.
	Merck Index, p. 960 (1968).
Amines	See CALCIUM HYPOCHLORITE plus Amines.
Ammonium Acetate	Decomposition of sodium hypochlorite takes place within a few seconds with the following salts: ammonium acetate, ammonium carbonate, ammonium nitrate, ammonium oxalate, and ammonium phosphate.
	Mellor **2, Supp. 1:** 550 (1956).
Ammonium Carbonate	See SODIUM HYPOCHLORITE plus Ammonium Acetate.
Ammonium Nitrate	See SODIUM HYPOCHLORITE plus Ammonium Acetate.
Ammonium Oxalate	See SODIUM HYPOCHLORITE plus Ammonium Acetate.
Ammonium Phosphate	See SODIUM HYPOCHLORITE plus Ammonium Acetate.
Cellulose	See SODIUM HYPOCHLORITE plus Oxalic Acid.
Ethyleneimine	See ETHYLENEIMINE plus Sodium Hypochlorite.

SODIUM HYPOPHOSPHITE $NaPH_2O_2$

(self-reactive)	Explosions can occur when hot sodium hypophosphite solution is evaporated.
	Mellor **8:** 881 (1946-1947).
Air	Sodium hypophosphite decomposes when heated, forming

	phosphine, a spontaneously flammable gas.
	Mellor **8:** 881 (1946-1947).
	Mellor **8, Supp. 3:** 623 (1971).
Chlorates	See CHLORATES plus Sodium Hypophosphite.
Nitrates	See CHLORATES plus Sodium Hypophosphite.
Potassium Nitrate	See POTASSIUM NITRATE plus Sodium Hypophosphite.
Sodium Nitrate	See SODIUM NITRATE plus Sodium Hypophosphite.

SODIUM IODATE $NaIO_3$

Aluminum	See ALUMINUM plus Bromates.
Arsenic	See ARSENIC plus Bromates.
Carbon	See CARBON plus Bromates.
Copper	See COPPER plus Bromates.
Hydrogen Peroxide	Iodates decompose hydrogen peroxide catalytically.
	Mellor **1:** 940 (1946-1947).
Metal Sulfides	See METAL SULFIDES plus Bromates.
Organic Matter	See ORGANIC MATTER plus Bromates.
Phosphorus	See PHOSPHORUS plus Bromates.
Potassium	See POTASSIUM plus Boric Acid.
Sulfur	See SULFUR plus Bromates.

SODIUM IODIDE NaI

Bromine Trifluoride	See BROMINE TRIFLUORIDE plus Potassium Bromide.
Perchloric Acid	Perchloric acid ignites in contact with sodium iodide.
	J. Am. Chem. Soc. **23:** 444 (1901).

SODIUM METHYL CH_3Na

(See METHYL SODIUM)

SODIUM METHYLATE

(See SODIUM METHOXIDE)

SODIUM METHOXIDE $NaOCH_3$

Chloroform	Too rapid addition of sodium methylate to a mixture of chloroform and methanol initiated an uncontrolled exothermic reaction between the chloroform and the methylate that terminated in a violent explosion.
	MCA Case History **693** (1961).
Methyl Azide and	See METHYL AZIDE plus Dimethyl Malonate
Dimethyl Malonate	and Sodium Methylate.
Perchloryl Fluoride	See PERCHLORYL FLUORIDE plus Sodium Methylate.
Water	Sodium methylate ignites in moist air.
	Wischmeyer (1966).

SODIUM MONOXIDE Na_2O

Nitric Oxide	Sodium monoxide and nitric oxide react vigorously above 100¡ C.
	Mellor **2, Supp. 2:** 629 (1961).

SODIUM NITRATE $NaNO_3$

Antimony	See ANTIMONY plus Potassium Nitrate.
Barium Rhodanide	See BARIUM RHODANIDE plus Sodium Nitrate.
Boron Phosphide	See BORON PHOSPHIDE plus Nitric Acid.
Cyanides	See NITRATES plus Cyanides.
Sodium Hypophosphite	A mixture of sodium nitrate and sodium hypophosphite constitutes a powerful explosive.

	Mellor **8:** 831 (1946-1947).
Sulfur and Charcoal	See SULFUR plus Sodium Nitrate and Charcoal.

SODIUM NITRIDE Na_3N

Air	The reactivity of sodium nitride resembles that of sodium metal.
	Mellor **8, Supp. 1:** 154 (1964).
Performic Acid	See PERFORMIC ACID plus Sodium Nitride.

SODIUM NITRITE $NaNO_2$

Ammonium Salts	A violent explosion occurs if an ammonium salt is melted with a nitrite salt.
	Von Schwartz, p. 299 (1918).
Cellulose	Sodium nitrite at 460¡F in contact with the fiber drums in which it is shipped undergoes a vigorous decomposition reaction producing a propellant-type burning until the carton is consumed.
	Wheeler (1969).
Cyanides	See CYANIDES plus Chlorates.
Lithium	See LITHIUM plus Sodium Nitrite.
Potassium and	See POTASSIUM plus Sodium Nitrite and
Ammonia	Ammonia.
Sodium Thiosulfate	When a sodium nitrite and thiosulfate mixture was heated to evaporate to dryness, a violent explosion occurred.
	Mellor **10:** 501 (1946-1947).

SODIUM NITROMETHANE

(See SODIUM ACI-NITROMETHYLIDE)

SODIUM-o-NITROPHENYL SULFIDE $NaSC_6H_4NO_2$

(self-reactive)	Methanol solutions of o-nitrothiophenol and sodium methoxide were mixed and evaporated under reduced pressure, dissolved in xylene and methanol and re-evaporated. As the flask was removed from the evaporator, it exploded.
	Chem. & Ind. **6:** 257 (Feb. 5, 1966).

SODIUM-o-NITROTHIOPHENATE

(See SODIUM-o-NITROPHENYL SULFIDE)

SODIUM OXIDE Na_2O

Water	See POTASSIUM OXIDE plus Water.

SODIUM OZONIDE NaO_3

Acids	Acids initiate a fast decomposition of sodium ozonate.
	Mellor **2, Supp. 2:** 641 (1961).
Water	Water initiates a fast decomposition of sodium ozonate.
	Mellor **2, Supp. 2:** 641 (1961).

SODIUM PERCHLORATE $NaClO_4$

Ammonium Nitrate	A mixture of these chemicals is used as an explosive.
	Mellor **2, Supp. 1:** 608 (1956).
Calcium Hydride	See BROMATES plus Calcium Hydride.
Charcoal	See PERCHLORATES plus Charcoal.
Magnesium	See MAGNESIUM plus Potassium Perchlorate.
Reducing Agents	See PERCHLORATES plus Charcoal.
Strontium Hydride	See BROMATES plus Calcium Hydride.

SODIUM PEROXIDE Na_2O_2

Acetic Acid	Acetic acid or acetic anhydride can explode with sodium peroxide if not kept cold.
	Von Schwartz, p. 321 (1918).
Acetic Anhydride	See SODIUM PEROXIDE plus Acetic Acid.
Aluminum	See ALUMINUM plus Sodium Peroxide.
Aluminum and	See ALUMINUM plus Sodium Peroxide and
Carbon Dioxide	Carbon Dioxide.
Ammonium Persulfate	See AMMONIUM PERSULFATE plus Sodium Peroxide.
Aniline	Sodium peroxide or potassium peroxide is spontaneously flammable with aniline, benzene, organic matter such as paper and wood, and diethyl ether. Mixtures with charcoal, glycerine, certain oils, and phosphorus burn or explode.
	Mellor **2:** 490-93 (1946-1947). *Von Schwartz,* p. 328 (1918).
Antimony	See ANTIMONY plus Sodium Peroxide.
Arsenic	See ARSENIC plus Sodium Peroxide.
Benzene	See SODIUM PEROXIDE plus Aniline.
Boron Nitride	See BORON NITRIDE plus Sodium Peroxide.
Calcium Carbide	When a mixture of sodium peroxide and calcium carbide (powdered) is exposed to damp air, spontaneous combustion occurs. The mixture explodes when heated.
	Mellor **2:** 490 ff. (1946-1947).
Charcoal	See SODIUM PEROXIDE plus Aniline.
Copper	See COPPER plus Sodium Peroxide.
Dextrose and	A micro Parr calorimeter exploded when the
Potassium Nitrate	wrong proportions of these ingredients were used. The intended mixture was 4.0 g sodium peroxide, 0.2 g dextrose, and 0.2 g potassium nitrate; actual proportions were 0.35 g, 2.59 g, and 0.2 g respectively. There was insufficient sodium peroxide to dissolve decomposition

	gases, hence a rapid temperature and pressure build-up caused the Parr bomb to burst.
	Tennessee Eastman (1967).
Diethyl Ether	See SODIUM PEROXIDE plus Aniline.
Glycerine	See SODIUM PEROXIDE plus Aniline.
Hexamethylene-tetramine	Sodium peroxide will ignite numerous organic compounds, e.g., hexamethylenetetramine, when the mixture is moistened.
	Ellern, p. 46 (1968).
	See also SODIUM PEROXIDE plus Aniline.
	See also SODIUM PEROXIDE plus Organic Matter.
Hydrogen Sulfide	See HYDROGEN SULFIDE plus Sodium Peroxide.
Magnesium	See MAGNESIUM plus Sodium Peroxide.
Magnesium and Carbon Dioxide	See MAGNESIUM plus Sodium Peroxide and Carbon Dioxide.
Manganese Dioxide	The catalyzed decomposition of sodium peroxide with manganese dioxide may be violent.
	Mellor **2, Supp. 2:** 635 (1961).
Organic Matter	When sodium peroxide is mixed with combustible materials, explosive mixtures may be formed. See also SODIUM PEROXIDE plus Aniline.
	Mellor **2:** 490 (1946-1947). *Ellern*, p. 46 (1968).
Phosphorus	See PHOSPHORUS plus Sodium Peroxide.
	See SODIUM PEROXIDE plus Aniline.
Potassium	See POTASSIUM plus Sodium Peroxide.
Selenium Monochloride	See SELENIUM MONOCHLORIDE plus Sodium Peroxide.
Silver Chloride and Charcoal	A mixture of sodium peroxide, silver chloride, and charcoal ignites spontaneously.
	Mellor **3:** 401 (1946-1947).

Sodium	See SODIUM plus Sodium Peroxide.
Sulfur Monochloride	A violent reaction results on mixing sodium peroxide and sulfur monochloride. *Mellor* **2, Supp. 2:** 634 (1961).
Tin	See TIN plus Sodium Peroxide.
Zinc	See ZINC plus Sodium Peroxide.

SODIUM PHOSPHIDE Na_3P

Water	In contact with water or damp air, sodium phosphide evolves phosphine, which is spontaneously flammable in air. *Lab. Govt. Chemist* (1965). *Van Wazer* (1958).

SODIUM PHOSPHINAMIDE $NaNHPH_2$

(self-reactive)	Sodium amino phosphide is spontaneously flammable in air. *Lehman and Wilson*, p. 50 (1949).

SODIUM POLYSULFIDE Na_2S_x

m-Chloroaniline Diazonium Salt	See SODIUM SULFIDE plus Diazonium and Diazonium Chloride Salts.
4-Chloro-o-toluidine Diazonium Chloride Salt	See SODIUM SULFIDE plus Diazonium and Diazonium Chloride Salts.
o-Nitroaniline Diazonium Salt	See SODIUM SULFIDE plus Diazonium and Diazonium Chloride Salts.

SODIUM-POTASSIUM ALLOY NaK

(See also the reactions listed separately under SODIUM and POTASSIUM)

Ammonium Sulfate and Ammonium Nitrate	See POTASSIUM plus Ammonium Sulfate and Ammonium Nitrate.
Bromoform	Mixtures of sodium-potassium alloy and bromoform, tetrachloroethane, or pentachloroethane can explode on standing at room temperature. They are especially sensitive to impact. *Mellor* **2, Supp. 2:** 563 (1961).
Carbon Dioxide	Solid carbon dioxide with sodium-potassium alloy will explode under a slight impact. H. Staudinger, *Z. Elektrochem.* **31:** 549-52 (1925). *Mellor* **2, Supp. 2:** 563 (1961).
Carbon Tetrachloride	If carbon tetrachloride is placed on sodium-potassium alloy, a light impact will cause a violent explosion. Chloroform, dichloromethane, or methyl chloride in contact with sodium-potassium alloy is similarly impact-sensitive. H. Staudinger, *Z. Elektrochem.* **31:** 549-52 (1925). *Ellern,* p. 43 (1968). Addition of a small amount of carbon tetrachloride to the alloy with a trace of kerosine and carbonaceous residue resulted in a violent explosion after a few moments. *Bozich* (1966). *Mellor* **2, Supp. 2:** 563 (1961). See also SODIUM-POTASSIUM ALLOY plus Water.
Chloroform	See SODIUM-POTASSIUM ALLOY plus Carbon Tetrachloride. See LITHIUM plus Chloroform.
Dichloromethane	See SODIUM-POTASSIUM ALLOY plus Carbon Tetrachloride.
Diiodomethane	Sodium-potassium alloy reacts explosively with diiodomethane. *Ellern,* p. 43 (1968).

Mercuric Oxide	Red mercuric oxide causes a violent explosion with sodium-potassium alloy when struck lightly; the yellow oxide does so at a much lighter blow.
	H. Staudinger, *Z. Elektrochem.* **31:** 549-52 (1925).
Methyl Chloride	See SODIUM-POTASSIUM ALLOY plus Carbon Tetrachloride.
Methyl Dichloride	The mixture of sodium-potassium alloy and methyl dichloride detonates strongly if struck.
	Mellor **2, Supp. 2:** 563 (1961).
Oxalyl Bromide	A mixture of sodium-potassium alloy and either oxalyl bromide or oxalyl chloride explodes violently.
	Mellor **2, Supp. 2:** 564 (1961).
Oxalyl Chloride	See SODIUM-POTASSIUM ALLOY plus Oxalyl Bromide.
Pentachloroethane	See SODIUM-POTASSIUM ALLOY plus Bromoform.
Potassium Oxides	See POTASSIUM plus Air.
Potassium Superoxide	While 100 gallons of sodium-potassium was being transferred and filtered into a receiver tank, the waste oxide accumulating on the filter was periodically scraped into drums. Drops of hot liquid NaK fell into one drum receiving the oxide waste, and a serious explosion occurred. Potassium superoxide was considered the essential ingredient of the explosive mixture.
	Health and Safety Inf. **251** (March 31, 1967).
Silicon	See SILICON plus Sodium-Potassium Alloy.
Silver Halides	Sodium-potassium alloys have exploded violently on contact with silver halides.
	Ellern, p. 43 (1968).
Sodium Bicarbonate	See SODIUM-POTASSIUM ALLOY plus Water.
Teflon	Sealing tape made of Teflon (polytetrafluoroethylene or polyhexafluoroethylene) burned vigorously in contact with sodium-potassium alloy in a helium atmosphere.
	Scott (1966).

Tetrachloroethane	See SODIUM-POTASSIUM ALLOY plus Bromoform.
1,1,1-Trichloroethane	A pipe- and solenoid-valve assembly used to transfer NaK had been purged with nitrogen, then flushed with water. Trichloroethane, used subsequently to remove traces of water, contacted a hidden residue of NaK in one valve and an explosion ensued.
	Inf. Exchange Bull. **1:** 2 (1961).
Trichlorotrifluoroethane	When two drops of the trichlorotrifluoroethane were added to NaK, there was a violent explosion.
	Pancner (1966).
Water	Sodium-potassium alloy undergoes a violent reaction with certain extinguishing agents: water, sodium bicarbonate, carbon tetrachloride.
	Mellor **2, Supp. 2:** 564 (1961).

SODIUM SILICATE $NaSiO_3$

Fluorine	See FLUORINE plus Sodium Silicate.

SODIUM SILICIDE Na_2Si_2

Air	Sodium silicide in powder form is spontaneously flammable in air.
	Ellern (1968).
Water	See CESIUM SILICIDE plus Water.

SODIUM SULFATE Na_2SO_4

Aluminum	See ALUMINUM plus Sulfates.

SODIUM SULFIDE Na_2S

Carbon	See CARBON plus Sodium Sulfide.
m-Chloroaniline	See SODIUM SULFIDE plus Diazonium and

Diazonium Salt	Diazonium Chloride Salts.
4-Chloro-o-toluidine Diazonium Chloride Salt	See SODIUM SULFIDE plus Diazonium and Diazonium Chloride Salts.
Diazonium Salts and Diazonium Chloride Salts	In the preparation of mercaptans, the slow addition of the diazonium chloride salt of 4-chloro-o-toluidine or o-nitroaniline or m-chloroaniline to sodium sulfide, sodium bisulfide or sodium polysulfide solutions will result in explosions even at 5¡C. *Chem. Eng. News* **23:** 1247 (1945). Hodgson, *Chem. & Ind.*, p. 362 (1945).
Diazonium Salts	See DIAZONIUM SALTS plus Thiophenates.
N, N-Dichloromethyl Amine	See N, N-DICHLOROMETHYL AMINE plus Sodium Sulfide.
o-Nitroaniline Diazonium Salt	See SODIUM SULFIDE plus Diazonium and Diazonium Chloride Salts.
Water	Moist sodium sulfide is spontaneously flammable upon drying in air. *Brauer* (1965).

SODIUM SUPEROXIDE NaO_2

(self-reactive)	Sodium superoxide violently evolves oxygen above 250¡ C. *Mellor* **2, Supp. 2:** 639 (1961).
Water	The reaction of sodium superoxide and water is fast and vigorous, liberating oxygen. *Mellor* **2, Supp. 2:** 639 (1961).

SODIUM TETRAHYDROALUMINATE $NaAlH_4$

Tetrahydrofuran	A violent explosion occurred during the preparation of

sodium aluminum hydride from sodium and aluminum in a medium of tetrahydrofuran. Localized heating in the reaction vessel was the suspected trigger mechanism.

Chem. Eng. News **39** (40): 57 (1961).

Water

On coming in contact with water sodium aluminum hydride ignites or explodes.

NSC Nat. Safety News **77** (2): 37-40 (1958).

SODIUM TETRAHYDROBORATE $NaBH_4$

Air

Sodium borohydride burns quietly in air.

Lab. Govt. Chemist (1965).

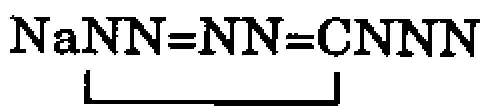
SODIUM TETRAPEROXYCHROMATE $Na_3Cr(OO)_4$

(self-reactive)

Sodium triperchromate decomposes explosively at 115¡ C.

Mellor **11:** 356 (1946-1947).

SODIUM TETRAZOLYL-5-AZIDE



(self-reactive)

Sodium tetrazolyl-5-azide is a shock-sensitive compound.

Chem. Eng. News **43** (52): 29, 30 (Dec. 27, 1965).

SODIUM THIOSULFATE $Na_2S_2O_3$

Sodium Nitrite

See SODIUM NITRITE plus Sodium Thiosulfate.

STAINLESS STEEL (**302**)

Fluorine	See FLUORINE plus Metals.

STANNIC BROMIDE $SnBr_4$

Nitryl Chloride	See NITRYL CHLORIDE plus Stannic Bromide.

STANNIC CHLORIDE $SnCl_4$

Potassium	See POTASSIUM plus Aluminum Bromide.
Sodium	See SODIUM plus Aluminum Bromide.
Turpentine	Stannic chloride reacts with turpentine, producing heat and sometimes flame.
	Mellor **7:** 430-46 (1946-1947).

STANNIC IODIDE SnI_4

Nitryl Chloride	See NITRYL CHLORIDE plus Stannic Bromide.
Potassium and Sulfur	See POTASSIUM plus Aluminum Bromide.
Sodium and Sulfur	See SODIUM plus Aluminum Bromide.

STANNIC OXIDE SnO_2

Chlorine Trifluoride	See CHLORINE TRIFLUORIDE plus Arsenic Trioxide.
Hydrogen Trisulfide	See HYDROGEN TRISULFIDE plus Stannic Oxide.
Magnesium	See MAGNESIUM plus Stannic Oxide.
Potassium	See POTASSIUM plus Stannic Oxide.
Sodium	See POTASSIUM plus Stannic Oxide.

STANNIC SULFIDE SnS_2

Cadmium Chlorate	Tin sulfides react with incandescence with chlorates of cadmium, magnesium, or zinc.

	Mellor **Supp. II, Part I:** 584 (1956).
Chloric Acid	Tin sulfides and concentrated solutions of chloric acid react with incandescence.
	Mellor **Supp. II, Part I:** 584 (1956).
Chlorine Monoxide	See CHLORINE MONOXIDE plus Calcium Phosphide.
Magnesium Chlorate	See STANNIC SULFIDE plus Cadmium Chlorate.
Zinc Chlorate	See STANNIC SULFIDE plus Cadmium Chlorate.

STANNOUS CHLORIDE $SnCl_2$

Bromine Trifluoride	See BROMINE TRIFLUORIDE plus Stannous Chloride.
Calcium Carbide	A mixture of stannous chloride and calcium carbide can be ignited with a match, and the reaction proceeds with incandescence.
	Mellor **7:** 430 (1946-1947).
Ethylene Oxide	See ETHYLENE OXIDE plus Aluminum Oxide. See ETHYLENE OXIDE plus Acids and Bases.
Hydrazine Hydrate	Hydrazine hydrate reacts with stannous chloride to give a compound, stannous dihydrazinechloride. When this compound is heated, it decomposes explosively.
	Mellor **7:** 430 (1946-1947).
Nitrates	See NITRATES plus Stannous Chloride.
Potassium	See POTASSIUM plus Aluminum Bromide.
Sodium	See SODIUM plus Aluminum Bromide.

STANNOUS FLUORIDE $SnFl_2$

Chlorine	See CHLORINE plus Stannous Fluoride.

STANNOUS NITRATE $Sn(NO_3)_2$

Organic Matter (flour)	In a flour-bleaching plant, dust found to contain tin nitrate was believed responsible for a violent decomposition

	explosion.
	J. Soc. Chem. Ind. **41:** 423-24R (1922).

STANNOUS OXIDE SnO

Sulfur Dioxide	When stannous oxide is heated in an atmosphere of sulfur dioxide, the reaction is attended by incandescence.
	Mellor **7:** 388 (1946-1947). Hammick, J.
	Chem. Soc. **III:** 379 (1917).

STANNOUS SULFIDE SnS

Cadmium Chlorate	Tin sulfides react with incandescence with chlorates of cadmium, magnesium, or zinc.
	Mellor **Supp. II, Part I:** 584 (1956).
Chloric Acid	Tin sulfides and concentrated solutions of chloric acid react with incandescence.
	Mellor **Supp. II, Part I:** 584 (1956).
Chlorine Monoxide	See CHLORINE MONOXIDE plus Calcium Phosphide.
Magnesium Chlorate	See STANNOUS SULFIDE plus Cadmium Chlorate.
Zinc Chlorate	See STANNOUS SULFIDE plus Cadmium Chlorate.

STEEL

Perchloric Acid	See PERCHLORIC ACID plus Steel.
Sulfuric Acid	See IRON plus Sulfuric Acid.

STIBINE SbH_3

Ammonia	An explosion occurs if stibine is heated with ammonia or chlorine.
	Mellor **9:** 397 (1946-1947).

Chlorine	See STIBINE plus Ammonia.
Nitric Acid	Stibine and concentrated nitric acid explode.
	Mellor **9:** 397 (1946-1947).
Ozone	See OZONE plus Stibine.

STRONTIUM ALLOYS

Acids	Alloys containing a substantial proportion of strontium react violently with acids.
	Lab. Govt. Chemist (1965).
Water	Alloys containing a substantial proportion of strontium rapidly decompose water. The heat of reaction is sufficient that the evolved hydrogen may ignite.
	Lab. Govt. Chemist (1965).

STRONTIUM CARBIDE SrC_2

Selenium	See SULFUR plus Strontium Carbide.
Sulfur	See SULFUR plus Strontium Carbide.

STRONTIUM CHLORATE $Sr(ClO_3)_2$

Acids	See CHLORATES plus Acids. See SODIUM CHLORATE plus Sulfuric Acid.

STRONTIUM CHLORIDE $SrCl_2$

2-Furan Percarboxylic Acid	See 2-FURAN PERCARBOXYLIC ACID (self-reactive).

STRONTIUM HYDRIDE SrH_2

Bromates	See BROMATES plus Strontium Hydride.

Chlorates	See BROMATES plus Strontium Hydride.
Perchlorates	See BROMATES plus Strontium Hydride.

STRONTIUM IODIDE SrI_2

Potassium	See POTASSIUM plus Ammonium Bromide.

STRONTIUM PHOSPHIDE Sr_3P_2

Bromine	See BROMINE plus Strontium Phosphide.
Chlorine	See CHLORINE plus Strontium Phosphide.
Fluorine	See FLUORINE plus Strontium Phosphide.

STYRENE MONOMER $CH_2{=}CHC_6H_5$

Chlorosulfonic Acid	Mixing styrene monomer and chlorosulfonic acid in a closed container caused the temperature and pressure to increase. *Flynn and Rossow* (1970). See Note under complete reference.
Oleum	See OLEUM plus Styrene Monomer.
Sulfuric Acid	Mixing styrene monomer and 96% sulfuric acid in a closed container caused the temperature and pressure to increase. *Flynn and Rossow* (1970). See Note under complete reference.

SULFAMIC ACID HSO_3NH_2

Chlorine	See CHLORINE plus Sulfamic Acid.
Nitric Acid	Fuming nitric acid combined with sulfamic acid causes violent release of nitrous oxide. *Mellor* **8, Supp. 2:** 316 (1967).

SULFATES

(See also specific sulfates as primary entries or under other reactants)

Aluminum	See ALUMINUM plus Sulfates.
Magnesium	See MAGNESIUM plus Sulfates.

SULFIDES

(See specific sulfides as primary entries or under other reactants)

SULFOLANE

Chrosoulfonic Acid	Mixing sulfolane and chlorosulfonic acid in a closed container caused the temperature and pressure to increase.
	Flynn and Rossow (1970). See Note under complete reference.
Oleum	See OLEUM plus Sulfolane.

SULFOXIDES

Perchloric Acid	The dialkyl sulfoxides form salts with perchloric acid. The lower members of the series are unstable, hydrolyze readily, and are explosive when dry.
	Chem. Abst. **44:** p. 3935d (1950).

SULFUR S

Aluminum	See ALUMINUM plus Nitrates.
Aluminum and Niobium Oxide	See ALUMINUM plus Niobium Oxide and Sulfur.
Ammonia	The reaction of ammonia with specially prepared sulfur

	may form explosive sulfur nitride.
	Mellor **8, Supp. 1:** 330 (1964).
Ammonium Nitrate	Ammonium nitrate mixed with sulfur or with metal powders can be exploded by shock.
	Kirk and Othmer **8:** 644. *Federoff* **1:** A-146.
Ammonium Perchlorate	Mixtures of ammonium perchlorate with sulfur, powdered metals, or carbonaceous materials are impact-sensitive.
	Haz. Chem. Data (1966).
Barium Bromate	See SULFUR plus Bromates.
Barium Carbide	A mixture of barium carbide and sulfur heated to 150¡C. becomes incandescent.
	Mellor **5:** 862 (1946-1947).
Barium Chlorate	See SULFUR plus Bromates. See SULFUR plus Chlorates.
	A mixture of sulfur and barium chlorate ignites at about 108¡ — 111¡C.
	Mellor **2, Supp. 1:** 583 (1956).
Barium Iodate	See SULFUR plus Bromates.
Boron	See BORON plus Sulfur.
Bromates	A combination of finely divided sulfur and finely divided bromates (also chlorates or iodates) of barium, calcium, magnesium, potassium, sodium, or zinc will explode with heat, percussion, and sometimes, light friction.
	Mellor **2:** 310 (1946-1947).
	Mellor **2, Supp. 1:** 763 (1956).
Bromine Pentafluoride	See ARSENIC plus Bromine Pentafluoride.
Bromine Trifluoride	See ANTIMONY plus Bromine Trifluoride.
Calcium	See CALCIUM plus Sulfur.
Calcium, Vanadium Oxide and Water	See CALCIUM plus Vanadium Oxide, Sulfur, and Water.

Calcium Bromate	See SULFUR plus Bromates.
Calcium Carbide	Calcium carbide reacts incandescently with sulfur vapor at 500¡C. *Mellor* **5:** 862 (1946-1947).
Calcium Chlorate	See SULFUR plus Bromates. See SULFUR plus Chlorates.
Calcium Hypochlorite	A mixture of damp sulfur and calcium hypochlorite produced a brilliant crimson flash with scattering of molten sulfur. No heat is necessary. Equal parts of sulfur and bleach powder produced an explosion when heated in a closed vessel. *Halane — Prelim. Info. Sheet. Mellor* **2:** 254-62 (1946-1947). *Chem. Eng. News* **46**(28):9 (1968).
Calcium Iodate	See SULFUR plus Bromates.
Calcium Phosphide	Calcium phosphide reacts with sulfur or oxygen incandescently at about 300¡C. *Mellor* **8:** 841 (1946-1947).
Cesium Nitride	See CESIUM NITRIDE plus Air.
Charcoal	Powdered sulfur is spontaneously flammable when mixed with lampblack or freshly calcined charcoal. *Von Schwartz,* p. 328 (1918).
Chlorates	A mixture of sulfur and barium chlorate, calcium chlorate, magnesium chlorate, potassium chlorate, sodium chlorate, or zinc chlorate may liberate oxygen and heat explosively. *Chem. Eng. News* **30:** 3210 (1952). *Von Schwartz,* p. 323 (1918). A mixture of chlorates and sulfur will explode. *Von Schwartz,* p. 328 (1918). *Ellern,* p. 47 (1968). See also SULFUR plus Bromates.
Chlorates and Copper	The sulfur-plus-chlorate explosion is remarkably spontaneous in the presence of copper ion or copper, e.g., in the form of bronze screen, even at room temperature. *Ellern,* p. 304 (1968).

Chlorine Dioxide	A piece of sulfur or sugar takes fire spontaneously in chlorine dioxide and may produce an explosion. *Mellor* **2:** 289 (1946-1947).
Chlorine Monoxide	See POTASSIUM plus Chlorine Monoxide.
Chlorine Trifluoride	See ANTIMONY plus Chlorine Trifluoride.
Chromic Anhydride	Sulfur and chromic anhydride ignite when heated and can explode. *Mellor* **10:** 102, 132-34; **11:** 232 (1946-1947).
Chromium Trioxide	See SULFUR plus Chromic Anhydride.
Chromyl Chloride	Flowers-of-sulfur moistened with chromyl chloride ignites spontaneously. *Mellor* **11:** 394-96 (1946-1947).
Fluorine	See FLUORINE plus Selenium.
Hydrocarbons	Even small percentages of hydrocarbons in contact with molten sulfur generate hydrogen sulfide and carbon disulfide, which may accumulate in explosive concentrations. *NAS-USCG Advis. Com.* (1966). *BM Report Invest.* **6185** (1963).
Indium	See INDIUM plus Sulfur.
Iodates	See SULFUR plus Bromates.
Iodine Pentafluoride	See ARSENIC plus Iodine Pentafluoride.
Iodine Pentoxide	See CARBON plus Iodine Pentoxide.
Lead Chlorate	A mixture of sulfur and lead chlorate ignites at about 63¡ — 67¡C. *Mellor* **2, Supp. 1:** 583 (1956). See also SULFUR plus Chlorates.
Lead Chlorite	A mixture of sulfur and lead chlorite will explode. *Von Schwartz,* p. 328 (1918).
Lead Dioxide	A mixture of sulfur and lead dioxide will explode.

	Von Schwartz, p. 328 (1918).
Lithium	See LITHIUM plus Sulfur.
Lithium Carbide	Lithium carbide burns in the vapor of sulfur or selenium.
	Mellor **5:** 848 (1946-1947).
Magnesium Bromate	See SULFUR plus Bromates.
Magnesium Chlorate	See SULFUR plus Bromates.
Magnesium Iodate	See SULFUR plus Bromates.
Mercuric Nitrate	An explosion occurred in the use of mercuric nitrate for determining sulfur in Ball's reaction.
	Chem. Eng. News **26:** 3300 (1948).
Mercuric Oxide	When mercuric oxide is heated with sulfur in a retort, a violent explosion results.
	Mellor **4:** 777 (1946-1947).
Mercurous Oxide	Mixture of the pulverized materials will ignite from light impact.
	J. B. Senderens, *Bull. Soc. Chim.* (3) **6:** 802 (1891).
Nickel	Powdered nickel heated with sulfur or selenium reacts with incandescence.
	Mellor **15:** 148,151 (1946-1947).
Nitrogen Dioxide	See MAGNESIUM plus Nitrogen Dioxide.
Palladium	See PALLADIUM plus Sulfur.
Perchlorates	All inorganic perchlorates can form mixtures with sulfur that will explode on impact.
	ACS **146:** 211-12. *BM Report Invest.* **4169** (1948).
Phosphorus	See PHOSPHORUS plus Sulfur.
Phosphorus Trioxide	The reaction is violent; small quantities should be used to avoid an explosion.
	Chem. Eng. News **27:** 2144 (1949).
	Mellor **8, Supp. 3:** 436 (1971).

Potassium	See POTASSIUM plus Aluminum Bromide.
	See POTASSIUM plus Sulfur.
Potassium Bromate	See SULFUR plus Bromates.
Potassium Chlorate	See SULFUR plus Bromates.
	A mixture of sulfur and potassium chlorate ignites at about 160¡ — 162¡C.
	Mellor **2, Supp. 1:** 583 (1956).
	See also SULFUR plus Chlorates.
Potassium Iodate	See SULFUR plus Bromates.
Potassium Nitrate and Arsenic Trisulfide	A mixture of these ingredients is a known pyrotechnic formulation.
	Ellern, p. 135 (1968).
Potassium Nitride	See PHOSPHORUS plus Potassium Nitride.
Potassium Perchlorate	This mixture, used in flashcrackers, can be exploded by a moderately strong impact.
	ACS **146:** 211. *Davis. BM Report Invest.* **4169** (1948).
Potassium Permanganate	When powdered sulfur is heated with potassium permanganate, an explosion may occur.
	Mellor **12:** 319 (1946-1947).
Rubidium Acetylene Carbide	See RUBIDIUM ACETYLENE CARBIDE plus Hydrochloric Acid.
	See PHOSPHORUS plus Rubidium Acetylene Carbide.
Selenium Carbide	See SULFUR plus Thorium Carbide.
Silver Bromate	An explosive reaction occurs in the presence of water.
	Mellor **2, Supp. 1:** 766 (1956).
Silver Chlorate	A mixture of sulfur and silver chlorate ignites at about 74¡C.
	Mellor **2, Supp. 1:** 583 (1956).

	See also SULFUR plus Chlorates.
Silver Nitrate	A mixture of silver nitrate and sulfur explodes when struck with a hammer.
	Mellor **3:** 469 (1946-1947).
Silver Oxide	When finely divided sulfur is ground with silver oxide, the mixture ignites.
	Mellor **3:** 376 (1946-1947).
Sodium	See SODIUM plus Sulfur.
Sodium Bromate	See SULFUR plus Bromates.
Sodium Chlorate	See SULFUR plus Bromates.
Sodium Chlorite	Solid sulfur will ignite if mixed with solid sodium chlorite and moistened.
	Mellor **2, Supp. 1:** 572 (1956).
Sodium Hydride	Sodium hydride reacts vigorously with sulfur vapor.
	Mellor **2:** 483 (1946-1947).
Sodium Iodate	See SULFUR plus Bromates.
Sodium Nitrate	The familiar black powder explosion begins
and Charcoal	with the reaction, sulfur-plus-sodium-nitrate, which produces the energy to initiate the carbon-plus-sodium-nitrate explosion.
	Trans. Faraday Soc. **55** (12):2221-8 (1959).
Sodium and Stannic Iodide	See SODIUM plus Aluminum Bromide.
Strontium Carbide	Strontium carbide mixed with selenium and heated to 500¡C., or exposed to sulfur vapor at 500¡C., becomes incandescent.
	Mellor **5:** 852 (1946-1947).
Sulfur Dichloride	See SODIUM plus Cobaltous Bromide.
Thallic Oxide	See THALLIC OXIDE plus Antimony Sulfide.
Thorium	Thorium when heated with sulfur reacts vigorously with incandescence.

	Mellor **7:** 208 (1946-1947).
Thorium Carbide	Sulfur vapor attacks heated thorium carbide or selenium carbide with incandescence.
	Mellor **5:** 885-87 (1946-1947).
Tin	The reaction between tin and sulfur is vigorous and accompanied by incandescence.
	Mellor **7:** 328 (1946-1947).
Uranium	See URANIUM plus Selenium.
Zinc	Powdered zinc and sulfur react explosively when warmed.
	Mellor **4:** 476 (1946-1947).
Zinc Bromate	See SULFUR plus Bromates.
Zinc Chlorate	See SULFUR plus Bromates.
Zinc Iodate	See SULFUR plus Bromates.

SULFUR DIBROMIDE SBr_9

Potassium	See POTASSIUM plus Aluminum Bromide.
Sodium	See SODIUM plus Aluminum Bromide.

SULFUR DICHLORIDE SCl_2

Aluminum	See ALUMINUM plus Carbon Disulfide.
Ammonia	The reaction product of sulfur dichloride and ammonia is a powerful detonating compound, sulfur nitride.
	Mellor **8:** 624 (1946-1947).
Potassium	See POTASSIUM plus Boron Tribromide.
Sodium	See SODIUM plus Cobaltous Bromide.
	See SODIUM plus Sulfur Dichloride.

SULFUR DIOXIDE SO_2

Acrolein	See ACROLEIN plus Sulfur Dioxide.
Aluminum	See ALUMINUM plus Carbon Disulfide.
Cesium Acetylene Carbide	See CESIUM ACETYLENE CARBIDE plus Sulfur Dioxide.
Cesium Monoxide	See CESIUM MONOXIDE plus Sulfur Dioxide.
Chlorates	See CHLORATES plus Sulfur Dioxide.
Chlorine Trifluoride	See CHLORINE TRIFLUORIDE plus Ammonia.
Chromium	See CHROMIUM plus Sulfur Dioxide.
Ferrous Oxide	See FERROUS OXIDE plus Sulfur Dioxide.
Fluorine	See FLUORINE plus Sulfur Dioxide.
Lithium Acetylene Carbide Diammino	See LITHIUM ACETYLENE CARBIDE DIAMMINO plus Carbon Dioxide.
Manganese	See MANGANESE plus Sulfur Dioxide.
Potassium Acetylene Carbide	See POTASSIUM ACETYLENE CARBIDE plus Sulfur Dioxide.
Potassium Chlorate	See POTASSIUM CHLORATE plus Sulfur Dioxide.
Rubidium Carbide	See RUBIDIUM CARBIDE plus Sulfur Dioxide.
Sodium	See SODIUM plus Sulfur Dioxide.
Sodium Carbide	See SODIUM CARBIDE plus Carbon Dioxide.
Stannous Oxide	See STANNOUS OXIDE plus Sulfur Dioxide.

SULFUR HEXAFLUORIDE SF_6

Disilane	See DISILANE plus Sulfur Hexafluoride.

SULFURIC ACID H_2SO_4

Acetic Anhydride	See ACETIC ANHYDRIDE plus Sulfuric Acid.
Acetone Cyanhydrin	See ACETONE CYANHYDRIN plus Sulfuric Acid.

Acetone and Nitric Acid	See NITRIC ACID plus Acetone and Sulfuric Acid.
Acetone and Potassium Dichromate	See ACETONE plus Sulfuric Acid and Potassium Dichromate.
Acetonitrile	See ACETONITRILE plus Sulfuric Acid.
Acrolein	See ACROLEIN plus Sulfuric Acid.
Acrylonitrile	See ACRYLONITRILE plus Sulfuric Acid.
Acrylonitrile and Water	See ACRYLONITRILE plus Sulfuric Acid and Water.
Alcohols and Hydrogen Peroxide	See ALCOHOLS plus Hydrogen Peroxide and Sulfuric Acid.
Allyl Alcohol	See ALLYL ALCOHOL plus Sulfuric Acid.
Allyl Chloride	See ALLYL CHLORIDE plus Sulfuric Acid.
	Allylchloride may polymerize violently under conditions involving an acid catalyst, such as sulfuric acid, ferric chloride, aluminum chloride, Lewis acids, and Ziegler type catalysts (initiators).
	Ventrone (1971).
2-Aminoethanol	See 2-AMINOETHANOL plus Sulfuric Acid.
Ammonium Hydroxide	Mixing 96% sulfuric acid and 28% ammonia in a closed container caused the temperature and pressure to increase.
	Flynn and Rossow (1970). See Note under complete reference.
Ammonium Triperchromate	See AMMONIUM TRIPERCHROMATE plus Sulfuric Acid.
Aniline	See ANILINE plus Sulfuric Acid.
Bromates and Metals	See CHLORATES plus Acids and Metals.
Bromine Pentafluoride	See BROMINE PENTAFLUORIDE plus Nitric Acid.
n-Butyraldehyde	See n-BUTYRALDEHYDE plus Sulfuric Acid.

Carbides	Sulfuric acid (concentrated) is extremely hazardous in contact with carbides, chlorates, fulminates, picrates and powdered metals.
	Chem. Safety Data Sheet **SD-20** (1963).
	Haz. Chem. Data (1966).
Cesium Acetylene Carbide	See CESIUM ACETYLENE CARBIDE plus Sulfuric Acid.
Chlorates	See SULFURIC ACID plus Carbides.
	See CHLORATES plus Acids.
	See CHLORATES plus Sulfuric Acid.
Chlorates and Metals	See CHLORATES plus Acids and Metals.
Chlorine Trifluoride	See CHLORINE TRIFLUORIDE plus Nitric Acid.
Chlorosulfonic Acid	See CHLOROSULFURIC ACID plus Sulfuric Acid.
Cuprous Nitride	See CUPROUS NITRIDE plus Sulfuric Acid.
Diisobutylene	See DIISOBUTYLENE plus Sulfuric Acid.
Dimethylbenzylcarbinol and Hydrogen Peroxide	See ALCOHOLS plus Hydrogen Peroxide and Sulfuric Acid.
Epichlorohydrin	See ETHYLENE CYANOHYDRIN plus Sulfuric Acid.
	See EPICHLOROHYDRIN plus Sulfuric Acid.
Ethyl Alcohol and Hydrogen Peroxide	See ALCOHOLS plus Hydrogen Peroxide and Sulfuric Acid.
Ethylene Cyanohydrin	See ETHYLENE CYANOHYDRIN plus Sulfuric Acid.
Ethylene Diamine	See ETHYLENE DIAMINE plus Sulfuric Acid.
Ethylene Glycol	See ETHYLENE GLYCOL plus Sulfuric Acid.
Ethylenimine	See ETHYLENIMINE plus Sulfuric Acid.
Fulminates	See SULFURIC ACID plus Carbides.

Hydrochloric Acid	See HYDROCHLORIC ACID plus Sulfuric Acid.
Hydrofluoric Acid	See HYDROFLUORIC ACID plus Sulfuric Acid.
Iodine Heptafluoride	See IODINE HEPTAFLUORIDE plus Sulfuric Acid.
Indane and Nitric Acid	See INDANE plus Nitric Acid and Sulfuric Acid.
Iron	See IRON plus Sulfuric Acid.
Isoprene	See ISOPRENE plus Sulfuric Acid.
Lithium Silicide	See LITHIUM SILICIDE plus Sulfuric Acid.
Mercuric Nitride	See MERCURIC NITRIDE plus Sulfuric Acid.
Mesityl Oxide	See MESITYL OXIDE plus Sulfuric Acid.
Metals (Powdered)	See SULFURIC ACID plus Carbides.
Nitric Acid and Glycerides	See NITRIC ACID plus Sulfuric Acid and Glycerides.
p-Nitrotoluene	See p-NITROTOLUENE plus Sulfuric Acid.
Pentasilver Trihydroxy-diaminophosphate	See PENTASILVER TRIHYDROXYDIAMINOPHOSPHATE plus Sulfuric Acid.
Perchlorates	See PERCHLORATES plus Sulfuric Acid.
Perchloric Acid	See PERCHLORIC ACID plus Sulfuric Acid.
Permanganates and Benzene	See PERMANGANATES plus Sulfuric Acid and Benzene.
1-Phenyl-2-methyl-propyl Alcohol and Hydrogen Peroxide	See ALCOHOLS plus Hydrogen Peroxide and Sulfuric Acid.
Phosphorus	See PHOSPHORUS plus Sulfuric Acid.
Phosphorus Isocyanate	See PHOSPHORUS ISOCYANATE plus Acetaldehyde.

Picrates	See SULFURIC ACID plus Carbides.
Potassium Tert.-Butoxide	See ACETONE plus Potassium Tert.-Butoxide.
Potassium Chlorate	See POTASSIUM CHLORATE plus Sulfuric Acid.
Potassium Permanganate	See POTASSIUM PERMANGANATE plus Sulfuric Acid.
Potassium Permanganate and Potassium Chloride	See POTASSIUM PERMANGANATE plus Sulfuric Acid and Potassium Chloride.
Potassium Permanganate and Water	See POTASSIUM PERMANGANATE plus Sulfuric Acid and Water.
Propiolactone (beta-)	See PROPIOLACTONE (beta-) plus Sulfuric Acid.
Propylene Oxide	See PROPYLENE OXIDE plus Sulfuric Acid.
Pyridine	See PYRIDINE plus Sulfuric Acid.
Rubidium Acetylene Carbide	See RUBIDIUM ACETYLENE CARBIDE plus Sulfuric Acid.
Silver Permanganate	See SILVER PERMANGANATE plus Sulfuric Acid.
Sodium	See SODIUM plus Sulfuric Acid.
Sodium Carbonate	See SODIUM CARBONATE plus Sulfuric Acid.
Sodium Chlorate	See SODIUM CHLORATE plus Sulfuric Acid. See CHLORATES plus Acids.
Sodium Hydroxide	See SODIUM HYDROXIDE plus Sulfuric Acid.
Steel	See IRON plus Sulfuric Acid.
Styrene Monomer	See STYRENE MONOMER plus Sulfuric Acid.
Toluene and Nitric Acid	See NITRIC ACID plus Toluene and Sulfuric Acid.
Vinyl Acetate	See VINYL ACETATE plus Sulfuric Acid.

Water	During sulfonation of mononitrobenzene by
	fuming sulfuric acid, a leak from an internal cooling coil permitted water to enter the tank.
	A violent eruption occurred due to the heat of solution.
	MCA Case History **944** (1963).
Zinc Chlorate	See ZINC CHLORATE plus Sulfuric Acid.
	See CHLORATES plus Acids.

SULFUR MONOCHLORIDE S_2Cl_2

Chromyl Chloride	See CHROMYL CHLORIDE plus Sulfur Monochloride.
Organic Matter	Sulfur chloride is strongly corrosive and can set fire to organic materials.
	B.L. Huestis, *Safety Eng.* **54:** 95 (1927).
Phosphorus Trioxide	See PHOSPHORUS TRIOXIDE plus Sulfur Monochloride.
Sodium Peroxide	See SODIUM PEROXIDE plus Sulfur Monochloride.
Water	The mixing of sulfur chloride and water can be dangerous.
	Chem. Safety Data Sheet **SD-77** (1960).

SULFUR NITRIDE S_4N_4

(self-reactive)	Sulfur nitride detonates violently on impact.
	Mellor **8:** 624 (1946-1947).
Air	Disulfur dinitride explodes when above 30¡C in air.
	Brauer (1965).
Barium Chlorate	Nitrogen sulfide and barium chlorate form very explosive crystals.
	Berichte **38:** 2659.

SULFUR TRIOXIDE SO_3

Dioxygen Difluoride	See DIOXYGEN DIFLUORIDE plus Sulfur Trioxide.
Lead Oxide	See LEAD OXIDE plus Sulfur Trioxide.
Nitryl Chloride	See NITRYL CHLORIDE plus Sulfur Trioxide.
Perchloric Acid	See PERCHLORIC ACID plus Sulfur Trioxide.
Phosphorus	See PHOSPHORUS plus Sulfur Trioxide.
Tetrafluorethylene	The reaction of sulfur trioxide in excess with tetrafluoroethylene causes explosive decomposition to carbonyl fluoride and sulfur dioxide. *Chem. Eng. News* **49** (22): 3 (1971).

SULFURYL CHLORIDE SO_2Cl_2

(See also THIONYL CHLORIDE)

Lead Dioxide	Reaction between sulfuryl chloride and lead dioxide can take place with explosive violence. *Mellor* **10:** 676 (1946-1947).

TANTALUM Ta

Air	Tantalum, thorium, titanium, and zirconium (powdered and dry) ignited when a glass container of the powder was thrown at a wall with force sufficient to break the container. *Chem. Eng. News* **30:** 3210 (1952).
Bromine Trifluoride	See NIOBIUM plus Bromine Trifluoride.
Fluorine	See FLUORINE plus Tantalum.

TANTALUM PENTOXIDE Ta_2O_5

Bromine Trifluoride	See BROMINE TRIFLUORIDE plus Bismuth Pentoxide.
Chlorine Trifluoride	See CHLORINE TRIFLUORIDE plus Aluminum Oxide.
Lithium	See LITHIUM plus Tantalum Pentoxide.

TARTARIC ACID HOOC.CHOHCHOHCO.OH

Silver	See SILVER plus Oxalic Acid.

TEFLON□ (**POLYTETRAFLUOROETHYLENE**) $(CF_2=CF_2)_x$

Fluorine	See FLUORINE plus Solid Nonmetals and Oxygen.
Oxygen	See OXYGEN plus Teflon□
Sodium-Potassium Alloy	See SODIUM-POTASSIUM ALLOY plus Teflon□

TELLURIUM Te

Cadmium	See ZINC plus Selenium.
Chlorine	See CHLORINE plus Tellurium.
Chlorine Fluoride	Tellurium is attacked by chlorine fluoride with incandescence. *Mellor* **11:** 26 (1946-1947).
Chlorine Trifluoride	See ANTIMONY plus Chlorine Trifluoride.
Fluorine	See FLUORINE plus Tellurium.
Lithium Silicide	See PHOSPHORUS plus Lithium Silicide.
Potassium	When tellurium and potassium are warmed in an atmosphere of hydrogen, combination occurs with incandescence. *Mellor* **11:** 40 (1946-1947).
Silver Bromate	A vigorous reaction occurs in the presence of moisture. *Mellor* **2, Supp. 1:** 766 (1956).
Sodium	See SODIUM plus Tellurium.
Zinc	See ZINC plus Selenium.

TELLURIUM DIETHYL $(C_2H_5)_2Te$

(See DIETHYL TELLURIDE)

TELLURIUM HYDROPENTACHLORIDE

(See TELLURIUM TETRACHLORIDE HYDROCHLORIDE)

TELLURIUM TETRACHLORIDE HYDROCHLORIDE $TeCl_4•HCl$

Ammonia	Tellurium hydropentachloride reacts with ammonia to produce a substance which detonates when heated, possibly nitrogen telluride. *Mellor* **11:** 101 (1946-1947).

TERBIUM Tb

Air	See RARE EARTH METALS plus Air.
Halogens	See RARE EARTH METALS plus Halogens.

TERPENES

Nitric Acid	See NITRIC ACID plus Diborane.

TETRAACETENYL NICKEL TETRAPOTASSIUM

(See POTASSIUM TETRAETHYNYLNICKELATE)

TETRABORANE (6) B_4H_6

Nitric Acid	The mixture of tetraboron decahydride and nitric acid is explosive. *Mellor* **5:** 36 (1946-1947).

TETRABORANE (10) B_4H_{10}

Air	See OXYGEN plus Boron Decahydride. This hydride ignites or explodes on exposure to air.
	Mellor **5:** 36 (1946-1947).
Nitric Acid	A mixture of boron decahydride and concentrated nitric acid explodes.
	Mellor **5:** 36 (1946-1947).
Oxygen	See OXYGEN plus Boron Decahydride.

TETRACHLOROBENZENE $Cl_4C_6H_2$

Sodium Hydroxide and Methyl Alcohol	See SODIUM HYDROXIDE plus Tetrachlorobenzene and Methyl Alcohol.

TETRACHLORODIBORANE B_2Cl_4

Air	Diboron tetrachloride is spontaneously flammable in air.
	Douda (1966). *Chem. Abst.* **49:** 2240d (1955).

TETRACHLOROETHANE (sym-) $Cl_2CHCHCl_2$

2, 4-Dinitrophenyl Disulfide	See 2, 4-DINITROBENZENE SULFENYLCHLORIDE (self-reactive).
Nitrogen Tetroxide	See NITROGEN TETROXIDE plus 1,2-Dichloroethane.
Potassium	See SODIUM plus Tetrachloroethane.
Potassium Hydroxide	See POTASSIUM HYDROXIDE plus Tetrachloroethane.
Sodium	See SODIUM plus Tetrachloroethane.
Sodium-Potassium Alloy	See SODIUM-POTASSIUM ALLOY plus Bromoform.

TETRACHLOROETHYLENE $CCl_2{=}CCl_2$

Barium	See BARIUM plus Trichlorotrifluoroethane.

Beryllium	See BERYLLIUM plus Carbon Tetrachloride.
Lithium	See LITHIUM plus Trichlorotrifluoroethane.

TETRAFLUOROETHYLENE $CF_2=CF_2$

Iodine Pentafluoride and Limonene	See IODINE PENTAFLUORIDE plus Tetrafluoroethylene and Limonene
Sulfur Trioxide	See SULFUR TRIOXIDE plus Tetrafluoroethylene.

TETRAFLUOROETHYLENE POLYMER

Fluorine	See FLUORINE plus Solid Metals and Oxygen.

TETRAFLUOROHYDRAZINE F_2NNF_2

Nitrogen Trifluoride	See NITROGEN TRIFLUORIDE plus Tetrafluorohydrazine.
Oxygen	See OXYGEN plus Tetrafluorohydrazine.

TETRAFLUOROMETHANE CF_4

Aluminum	See ALUMINUM plus Dichlorodifluoromethane.

1,2,3,4-TETRAHYDROCARBAZOLE

$$(C_6H_4NHC_6H_8)$$

Acrylonitrile

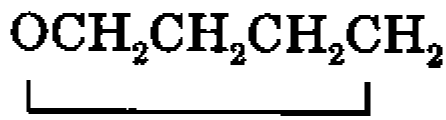
The reaction of 1,2,3,4-tetrahydrocarbazole with acrylonitrile, initiated by benzyl-tremethyl-ammonium hydroxide, is described in

J. Am. Chem. Soc. **72:** 4313 (1960). For a run, eight times the literature scale of the initiator was added at 0¡C, the ice bath removed, the reaction flask placed on the steam bath and the steam turned on. After 30-60 seconds an explosion shattered the apparatus.

BCISC **39** (156): 36 (1968). *Wischmeyer* (1970).

NSC Newsletter, R & D Sec. (Feb. 1970).

TETRAHYDROFURAN



Air

Purified tetrahydrofuran should not be stored for more than a few months after its container has been opened if it contains no oxidation inhibitor. In this case, it is potentially explosive because of peroxide formation.

NSC Newsletter, Chem. Sec. (Nov. 1964).

Lithium Aluminum Hydride

Fire can occur when tetrahydrofuran is used as a solvent for lithium aluminum hydride. Peroxides of tetrahydrofuran or their reaction products probably caused a vigorous reaction with lithium aluminum hydride, and subsequent fire.

MCA Guide for Safety, Appendix 3 (1972).

Potassium Hydroxide

Using potassium hydroxide to dry impure tetrahydrofuran, which can contain peroxides, is hazardous. Serious explosions can occur. This reaction will also occur with sodium hydroxide.

NSC Newsletter, Chem. Sec. (March 1967).

Wischmeyer (1967).

Sodium Aluminum Hydride

See SODIUM ALUMINUM HYDRIDE plus Tetrahydrofuran.

Sodium Hydroxide

See TETRAHYDROFURAN plus Potassium Hydroxide.

TETRAIODOETHYLENE $I_2HC=CHI_2$

Iodine Pentafluoride	See IODINE PENTAFLUORIDE plus Tetraiodoethylene.

TETRAMETHYLAMMONIUM CHLORITE $(CH_3)_4NH_4ClO_2$

(self-reactive)	Tetramethylammonium chlorite explodes on percussion.
	Mellor **2, Supp. 1:** 573 (1956).

TETRAMETHYLDIALUMINUM $(CH_3)_2HAl_2H(CH_3)_2$

Air	Tetramethyl dialuminum is spontaneously flammable in air.
	Hurd, p. 98 (1952).

TETRAMETHYLDIARSINE $(CH_3)_2As_2(CH_3)_2$

Air	Tetramethyl diarsine ignites spontaneously in dry air.
	Brauer (1965). *Douda* (1966).
Chlorine	See CHLORINE plus Tetramethyl Diarsine.

TETRAMETHYLDIBORANE $H(CH_3)_2B_2(CH_3)_2H$

Air	Tetramethyl diborane is spontaneously flammable in air.
	Lehman and Wilson, p. 50 (1949).

TETRAMETHYLDIGALLINE $(CH_3)_2Ga_2(CH_3)_2$

Air	Tetramethyl digalline is spontaneously flammable in air.
	Douda (1966).

TETRAMETHYLDISTIBINE $(CH_3)_2Sb_2(CH_3)_2$

Air	Tetramethyl distibine is spontaneously flammable in air.

Coates, p. 156 (1956).

TETRAMETHYLSILICANE $Si(CH_3)_4$

Air | Tetramethyl silicane is spontaneously flammable in air. *Douda* (1966).

TETRAMETHYLSILANE $Si(CH_3)_4$

(See TETRAMETHYL SILICANE)

TETRAMMINOCUPRIC CHLORATE $Cu(NH_3)_4(ClO_3)_2$

(See CUPRIC-TETRAMMINE CHLORATE)

TETRAMMINOCUPRIC PERCHLORATE $Cu(NH_3)_4(ClO_4)_2$

(See CUPRIC-TETRAMMINE PERCHLORATE)

TETRAMMINODIAZIDOCOBALTIC AZIDE $Co(N_3)_2(NH_3)_4N_3$

(See COBALTIC-TETRAMMINE AZIDE)

TETRAMMINOZINC CHLORATE $Zn(NH_3)_4(ClO_3)_2$

(See ZINC-TETRAMMINE CHLORATE)

TETRAMMINOZINC PERCHLORATE $Zn(NH_3)_4(ClO_4)_2$

(See ZINC-TETRAMMINE PERCHLORATE)

TETRANITROMETHANE $C(NO_2)_4$

(self-reactive) | This compound is a weak, but highly sensitive explosive.

	Van Dolah (1967).
Hydrocarbons	Hydrocarbons exposed to tetranitromethane form exceedingly sensitive explosives.
	Van Dolah (1967).

TETRAPHENYLDIARSINE $(C_6H_5)_2As_2(C_6H_5)_2$

Air	Tetraphenyl diarsine is spontaneously flammable in air.
	Ellern (1961).

TETRAPHOSPHORUS TRIIODIDE P_4I_3

Nitric Acid	Concentrated nitric acid attacks phosphorus tetratriiodide vigorously, accompanied by flame.
	Comp. Rend. **141:** 257.

TETRAPHOSPHORUS TRISELENIDE P_4Se_3

Air	Phosphorus tetratriselenide ignites when warmed in air.
	Z. Anorg. Chemie **30:** 258.

TETRASILANE Si_4H_{10}

Air	See TRISILANE plus Air; also SILANES plus Air.
Carbon Tetrachloride	Carbon tetrachloride reacts more vigorously on trisilane and tetrasilane than on disilane.
	Mellor **6:** 224 (1946-1947).
Oxygen	See OXYGEN plus Disilane.

TETRASILVER TRIHYDROXYDIAMINOPHOSPHATE

(See SILVER DIAMIDOTRIOXYPHOSPHORANE)

TETRYL $(NO_2)_3C_6H_2N(CH_3)NO_2$

Hydrazine	See HYDRAZINE plus Tetryl.

THALLIC NITRATE TRIHYDRATE Tl $(NO_3)_3$•$3H_2O$

Formic Acid and Vanillin	A violent reaction occurred when a small amount of vanillin was added to thallium trinitrate trihydrate (up to 50%) in 90% formic acid.
	Dean (1973).

THALLIC OXIDE Tl_2O_3

Antimony Sulfide	A mixture of thallic oxide and antimony sulfide or sulfur explodes when ground in a mortar.
	Mellor **5:** 421, 434 (1946-1947).
Sulfur	See THALLIC OXIDE plus Antimony Sulfide.

THALLIUM Tl

Fluorine	See FLUORINE plus Thallium.

THALLIUM TRIMETHYL $(CH_3)_3Tl$

(See TRIMETHYL THALLIUM)

THALLOUS AMIDE $TlNH_2$

Acids	Thallium amide explodes with dilute acids or water.
	Mellor **8:** 2, 5, 70, 261 (1946-1947).
Water	See THALLIUM AMIDE plus Acids.

THALLOUS AZIDE TlN_3

(self-reactive)	Thallous azide decomposes at 334¡C. It is almost as unstable as the copper salt.
	Mellor **8, Supp. 2:** 43 (1967).

THALLOUS BROMIDE TlBr

Potassium	See POTASSIUM plus Aluminum Bromide.
Sodium	See SODIUM plus Aluminum Bromide.

THALLOUS CHLORIDE TlCl

Fluorine	See FLUORINE plus Thallous Chloride.
Potassium	See POTASSIUM plus Ammonium Bromide.

THALLOUS NITRIDE Tl_3N

(self-reactive)	See THALLIUM NITRIDE plus Water.
Acids	Thallium nitride explodes with dilute acids or water.
	Mellor **8:** 2, 5, 70, 271 (1946-1947).
Water	Thallium nitride explodes with great violence when subjected to shock or heat, or when treated with water or dilute acids.
	Mellor **8:** 262 (1946-1947).

THALLOUS PHOSPHIDE Tl_3P

Air	This salt ignites if heated in air.
	Mellor **8, Supp. 3:** 312 (1971).

THERMITE

(See ALUMINUM plus Iron Oxide.)

THIANTHRENE PERCHLORATE

$$(C_6H_4S_2C_6H_4)\cdot HClO_4$$

(self-reactive)	A new batch of 1-2 grams of thianthrene perchlorate exploded violently while being transferred from a sintered glass filter to a Petri dish. *BCISC **40** (158): 17 (1969).*

THIOCYANATES RSCN

Chlorates	Thiocyanates and chlorates or nitrates explode when fused. If intimately mixed, the mixture explodes at a temperature of 750¡F., or when touched by flame or sparks. *Von Schwartz,* pp. 299-300 (1918). See also CHLORATES plus Antimony Sulfide.
Nitrates	See THIOCYANATES plus Chlorates.
Nitric Acid	When thiocyanate solution was introduced into a pipeline containing nitric acid, an explosion ruptured the line. *MCA Case History* **853** (1962).
Organic Peroxides	See THIOCYANATES plus Oxidizing Agents.
Oxidizing Agents	Caution should be exercised in treating a thiocyanate with an oxidizing agent such as a peroxide since such mixtures have been known to explode. *Kharasch* Vol. 1, p. 312 (1961).
Peroxides	See THIOCYANATES plus Oxidizing Agents.
Potassium Chlorate	See THIOCYANATES plus Chlorates.
Sodium Chlorate	See THIOCYANATES plus Chlorates.

THIODIGLYCOL $(HOCH_2CH_2)_2S$

Hydrogen Peroxide and Acetone	Thiodiglycol was being oxidized with an excess of hydrogen peroxide using acetone as a solvent. At the conclusion the acetone and excess hydrogen peroxide were removed under vacuum in a steam bath. After about 15 minutes of heating on a steam bath, a violent explosion occurred.
	MCA Case History 223 (1962).

THIONYL CHLORIDE $OSCl_2$

Dimethyl Sulfoxide	See DIMETHYL SULFOXIDE plus Acyl Halides.
2, 4-Hexadiyn-1, 6-Diol	Thionyl chloride and 2, 4-hexadiyn-1, 6-diol reacting in dimethyl formamide forms 2, 4-hexadiyn-1, 6-bischlorosulfite which is shock sensitive and decomposes violently upon distillation.
	P.E. Driedger and H.V. Isaacson, *Chem. Eng. News* **50** (12): 51 (1972).
o-Nitrobenzoylacetic Acid	o-Nitrobenzoylacetic acid reacted with thionyl chloride to produce the corresponding nitrobenzoylacetyl chloride, which decomposed violently after removal of solvent by distillation. A similar reaction hazard exists for o-nitrophenylacetic acid plus thionyl chloride.
	W.D. Bonner and C.O. Hurd, *J. Am. Chem. Soc.* **68:** 344 (1946).
o-Nitrophenylacetic Acid	See THIONYL CHLORIDE plus o-Nitrobenzoylacetic Acid.
Water	A flexible stainless hose that was being used for thionyl chloride transfer ruptured when contaminated with water. Water reacts with thionyl chloride, liberating hydrogen chloride and sulfur dioxide gases.
	Wischmeyer (1972).

THIOPHENATES

(See PHENYL SULFIDE SALTS)

THIOPHENE

Nitric Acid	A mixture of the two may cause an explosion.
	Pieters, p. 30 (1957).

THIOPHOSPHORYL FLUORIDE SPF_3

Air	Thiophosphoryl fluoride is spontaneously flammable in air; under proper conditions, it is spontaneously explosive.
	Mellor **8:** 1072 (1946-1947).
Potassium	See SODIUM plus Thiophosphoryl Fluoride.
Sodium	See SODIUM plus Thiophosphoryl Fluoride.

THIOUREA $S{=}C(NH_2)_2$

Acrolein	See ACROLEIN plus Sulfur Dioxide.

THORIUM Th

Air	See TANTALUM plus Air.
Chlorine	Thorium, when heated with chlorine, reacts vigorously with incandescence.
	Mellor **7:** 208 (1946-1947).
Phosphorus	See PHOSPHORUS plus Thorium.
Sulfur	See SULFUR plus Thorium.

THORIUM CARBIDE ThC_2

Air	When heated in air, thorium carbide readily burns with incandescence.
	Mellor **5:** 885-87 (1946-1947).
Selenium	See SELENIUM plus Thorium Carbide.
Sulfur	See SULFUR plus Thorium Carbide.

THORIUM HYDRIDE ThH_4

Air	Thorium hydride explodes if heated in the presence of air.
	Mellor **7:** 207-8 (1946-1947).

THORIUM NITRIDE Th_3N_4

Air	Thorium nitride burns in air with incandescence.
	Mellor **8:** 121-22 (1946-1947).
Water	Thorium nitride hydrolyzes vigorously.
	Mellor **8, Supp. 1:** 182 (1964).

THORIUM OXYSULFIDE ThOS

Air	Thorium oxysulfide ignites spontaneously in air.
	Mellor **7:** 240 (1946-1947).

THORIUM PHOSPHIDE Th_3P_4

Acids	Thorium phosphide reacts with acids to release spontaneously flammable phosphine.
	Mellor **8, Supp. 3:** 348 (1971).

THULIUM Tm

Air	See RARE EARTH METALS plus Air.
Halogens	See RARE EARTH METALS plus Halogens.

TIN Sn

(For tin compounds see STANNIC and STANNOUS compounds)

Bromine	The violent reaction between these chemicals is controlled in halocarbon solutions.
	Mellor **2, Supp. 1:** 715 (1956).
Bromine Trifluoride	Tin and bromine trifluoride react violently.
	Mellor **2, Supp. 1:** 164 (1956).
Chlorine	When heated in chlorine, tin reacts, producing light and much heat.
	Mellor **7:** 436 (1946-1947).
	Mellor **2, Supp. 1:** 380 (1956).
Chlorine Trifluoride	See ALUMINUM plus Chlorine Trifluoride.
Cupric Nitrate	In the presence of water, cupric nitrate and tin foil, on prolonged and intimate contact, will produce flaming and sparking.
	Ellern, p. 46 (1968).
Potassium Peroxide	See POTASSIUM plus Potassium Peroxide.
Sodium Peroxide	Sodium peroxide oxidizes tin with incandescence.
	Mellor **2:** 490-93 (1946-1947).
Sulfur	See SULFUR plus Tin.

TITANIUM Ti

Air	Most finely divided forms of titanium are flammable in air. See also TITANIUM DICHLORIDE plus Air and TANTALUM plus Air.
	NSC Data Sheet **485.** *BM Report Invest.* **6516** (1964). *BM Report Invest.* **4835** (1951).

Bromine Trifluoride	See MOLYBDENUM plus Bromine Trifluoride.
Carbon Dioxide	Titanium burns in carbon dioxide above 550¡C.
	NSC Data Sheet **485.**
Cupric Oxide	Titanium reacts violently with cupric oxide or lead oxide when heated.
	Mellor **7:** 20 (1946-1947).
Fluorine	See FLUORINE plus Titanium.
Lead Oxide	See TITANIUM plus Cupric Oxide.
Nickel and Potassium Perchlorate	See NICKEL plus Titanium and Potassium Perchlorate.
Nitric Acid	The residue from the reaction of titanium with red fuming nitric acid exploded violently when the flask was touched.
	Allison (1969).
Nitrogen	Titanium burns vigorously in free nitrogen above 802¡C.
	NSC Data Sheet **485**.
Oxygen	*Liquid* oxygen gives a detonable mixture when combined with powdered titanium.
	Kirschenbaum (1956).
Potassium Chlorate	When titanium is heated with potassium chlorate, potassium nitrate or potassium permanganate, an explosion occurs.
	Mellor **7:** 20 (1946-1947).
Potassium Nitrate	See TITANIUM plus Potassium Chlorate.
Potassium Permanganate	See TITANIUM plus Potassium Chlorate.
Steam	Titanium at red heat, 704¡C., decomposes steam. The hydrogen evolved burns or explodes.
	NSC Data Sheet **485.**
Trichloroethylene	It has been determined experimentally that a mixture of

	titanium powder with trichloroethylene or with trichlorotrifluoroethane will flash or spark on heavy impact.
	ASESB Pot. Incid. **39** (1968).
Trichlorotrifluoroethane	See TITANIUM plus Trichloroethylene.

TITANIUM ALLOY

Nitric Acid	Extreme caution is urged in handling of all titanium alloys exposed to red fuming nitric acid since the reaction may cause an explosion.
	Chem. Eng. News **31:** 3320 (1953).
Oxygen	A titanium alloy tank containing liquid oxygen exploded during a laboratory experiment. Contamination might have triggered the reaction. An explosion hazard may exist in the use of titanium with either gaseous or liquid oxygen.
	MCA Case History **988** (1964). *Jolicoeur* (1966).

TITANIUM CARBIDE TiC

Air	As micron-sized titanium carbide was being removed from a ball mill, a cloud of the dust ignited.
	MCA Case History **618** (1960).

TITANIUM DICHLORIDE $TiCl_2$

Air	Titanium dichloride is highly flammable in air at room temperature. In inert gases, titanium dichloride converts to titanium tetrachloride plus very finely divided titanium metal, which can ignite on subsequent exposure to air.
	NSC Data Sheet **485.**

TITANIUM DIOXIDE TiO_2

Lithium	See LITHIUM plus Titanium Dioxide.

TITANIUM DISULFIDE TiS_2

Potassium Nitrate	A mixture of titanium disulfide and potassium nitrate detonated when heated.
	Mellor **7:** 91 (1946-1947).

TITANIUM-MAGNESIUM ALLOY

Nitric Acid	The residue from the reaction of titanium-magnesium alloy with red-fuming nitric acid may be detonated by friction, heat, or shock.
	Chem. Eng. News **31:** 3320 (1953).

TITANIUM TETRACHLORIDE $TiCl_4$

Potassium	See POTASSIUM plus Titanium Tetrachloride.

TOLUENE $C_6H_5CH_3$

Nitric Acid and Sulfuric Acid	See NITRIC ACID plus Toluene and Sulfuric Acid.
Nitrogen Tetroxide	See NITROGEN TETROXIDE plus Toluene.
Silver Perchlorate	See SILVER PERCHLORATE plus Acetic Acid.
	See SILVER PERCHLORATE plus Toluene.

TOLUIDINE $CH_3(C_6H_4)NH_2$

Nitric Acid	See NITRIC ACID plus Aniline.

TOLYL CHLORIDE $C_6H_5CH_2Cl$

Dimethyl Sulfoxide	See DIMETHYL SULFOXIDE plus Acyl Halides.

TRIALLYL PHOSPHATE $(CH_2{=}CHCH_2O)_3PO$

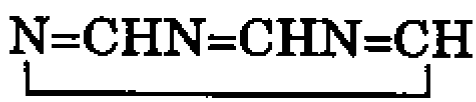
(self-reactive) An explosion occurred on distilling triallyl phosphate prepared from phosphorus oxychloride, allyl alcohol and pyridine. The toluene solution of the product, washed with sodium carbonate and with pyrogallol added, exploded violently while being distilled under vacuum at 135¡C.

W.T. Dye, G.E. Ham, *Chem. Eng. News* **28:** 3452 (1950).

TRIAMMINOTRIAZIDOCOBALT $Co(N_3)_3(NH_3)_3$

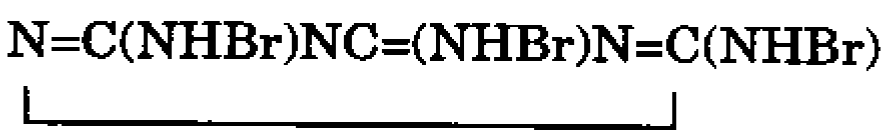
(See COBALTIC-TRIAMMINE AZIDE)

TRIAZINE



Nitric Acid See NITRIC ACID plus Triazine.

TRI-n-BROMOMELAMINE



Ally Alcohol See ALLYL ALCOHOL plus Tri-n-Bromomelamine.

TRIBROMONEOPENANOL (Sym) $(BrCH_{2-})_3COH$

Ethyl Acetoacetate and Zinc See ETHYL ACETOACETATE plus Tribromoneopentyl Alcohol and Zinc.

TRIBROMOTRIETHOXYDIALUMINUM $Al_2Br_3(OC_2H_5)_3$

Air	See TRIBROMOTRIETHOXYDIALUMINUM plus Ethyl Alcohol.
Ethyl Alcohol	Aluminum sesquibromide ethylate explodes on contact with ethyl alcohol or water. It is also pyrophoric.
	Chem. Eng. Progs. **62** (9): 128 (1968).
Water	See TRIBROMOTRIETHOXYDIALUMINUM plus Ethyl Alcohol.

TRIBROMOTRIMETHYLDIALUMINUM $(CH_3)_3Al_2Br_3$

Air	Trimethyl tribromo dialuminum is spontaneously flammable in air.
	Douda (1966).
Water	Trimethyl tribromo dialuminum reacts violently with water.
	Rose (1961).

TRIBUTYLALUMINUM $(C_4H_9)_3Al$

Air	Tri-n-butyl aluminum is spontaneously flammable in air.
	Rose (1961).

TRIBUTYLBORANE $(C_4H_9)_3B$

Air	Tri-n-butyl borane, if spread over a large area, ignites spontaneously in air.
	W.H. Johnson et al., *J. Res. Nat. Bur. Stand.* **62** (1): 49 (1959).

TRIBUTYLPHOSPHINE $P(C_4H_9)_3$

Air	Tributyl phosphine is spontaneously flammable in air.
	A.B. Steele and J.J. Duggan, *Chem. Eng.* **66:** 160 (April

	1969).

2,6,-N-TRICHLOROBENZOQUINONIMINE $OC_6H_2(Cl)_2NCl$

(self-reactive)	See 2,6-DIBROMO-N-CHLOROBENZOQUINONIMINE (self-reactive).

1,1,1-TRICHLOROETHANE CCl_3CH_3

Acetone	See ACETONE plus Methyl Chloroform.
Nitrogen Tetroxide	See NITROGEN TETROXIDE plus 1,2-Dichloroethane.
Oxygen	See OXYGEN plus 1,1,1-Trichloroethane.
Oxygen (Liquid)	See OXYGEN (LIQUID) plus Chlorinated Hydrocarbons.
Sodium	See SODIUM plus 1,2-Dichloroethylene.
Sodium Hydroxide	See SODIUM plus 1,2-Dichloroethylene.
Sodium-Potassium Alloy	See SODIUM-POTASSIUM ALLOY plus 1,1,1-Trichloroethane.

TRICHLOROETHYLENE $Cl_2C{=}CHCl$

Aluminum	See ALUMINUM plus Trichloroethylene.
Barium	See BARIUM plus Trichlorotrifluoroethane.
Nitrogen Tetroxide	See NITROGEN TETROXIDE plus 1,2-Dichloroethane.
Lithium	See LITHIUM plus Trichlorotrifluorethane.
Magnesium	See MAGNESIUM plus Trichloroethylene.
Oxygen (Liquid)	See OXYGEN (LIQUID) plus Chlorinated Hydrocarbons.
Oxygen	See OXYGEN plus Trichloroethylene.
Potassium Hydroxide	See SODIUM HYDROXIDE plus Trichloroethylene.
Potassium Nitrate	A batch of 3257 grams of boron, 9362 grams of potassium nitrate, 989 grams of laminac, and 500 grams of trichloroethylene had been mixing for 5 minutes, when an

	explosion occurred.
	MCA Guide for Safety, Appendix 3 (1972).
Sodium	See SODIUM plus 1,2-Dichloroethylene.
Sodium Hydroxide	See SODIUM HYDROXIDE plus Trichloroethylene. See also SODIUM plus 1,2-Dichloroethylene.
Titanium	See TITANIUM plus Trichloroethylene.

TRICHLOROETHYLSILANE $C_2H_5SiCl_3$

Water	Ethyltrichlorosilane reacts violently with water.
	Title 46 (1970).

1,1,1-TRICHLORO-2-FLUOROETHANE CCl_3CH_2F

Barium	See BARIUM plus Trichlorotrifluoroethane.

TRICHLOROFLUOROMETHANE $CFCl_3$

Aluminum	See ALUMINUM plus Chlorofluorohydrocarbons. See also ALUMINUM plus Dichlorodifluoromethane.
Lithium	See LITHIUM plus Trichlorotrifluoroethane.

TRICHLOROMELAMINE $C_3N_3(NHCl)_3$

Acetone	See HEXACHLOROMELAMINE plus Organic Contaminants.
Ammonia	See HEXACHLOROMELAMINE plus Organic Contaminants.
Aniline	See HEXACHLOROMELAMINE plus Organic Contaminants.
Diphenylamine	See HEXACHLOROMELAMINE plus Organic Contaminants.
Turpentine	See HEXACHLOROMELAMINE plus Organic

	Contaminants.

TRICHLOROMETHYL PERCHLORATE $Cl_3C(ClO_4)$

(self-reactive)	See SILVER PERCHLORATE plus Carbon Tetrachloride and Hydrochloric Acid.

TRICHLOROMETHYLSILANE CH_3SiCl_3

Water	Methyl trichlorosilane evolves white fumes with moist air. It reacts violently with water with the evolution of heat and white acid fumes.
	Title 46 (1970).

TRICHLOROTRIETHYLDIALUMINUM $(C_2H_5)_3Al_2Cl_3$

Air	Ethyl aluminum sesquichloride is spontaneously flammable in air.
	Douda (1966).
Benzene and Allyl Chloride	See ALLYL CHLORIDE plus Benzene and Ethyl Aluminum Dichloride.
Carbon Tetrachloride	See ALUMINUM TRIETHYL plus Carbon Tetrachloride.
Toluene and Allyl Chloride	See ALLYL CHLORIDE plus Benzene and Ethyl Aluminum Dichloride.
Water	Ethyl aluminum sesquichloride reacts violently with water.
	Rose (1961).

1,1,2-TRICHLOROTRIFLUOROETHANE CCl_3CF_3

Aluminum	See ALUMINUM plus Chlorofluorohydrocarbons.
	See also ALUMINUM plus Dichlorodifluoromethane.
Barium	See BARIUM plus Trichlorotrifluoroethane.

Lithium	See LITHIUM plus Trichlorotrifluoroethane.
Samarium	See SAMARIUM plus 1,1,2-Trichlorotrifluoroethane.
Sodium-Potassium Alloy	See SODIUM-POTASSIUM ALLOY plus Trichlorotrifluoroethane.
Titanium	See TITANIUM plus Trichloroethylene.

TRICHLOROTRIMETHYLDIALUMINUM $(CH_3)_3Al_2Cl_3$

Air	Methyl aluminum sesquichloride ignites instantly in air.
	Rose (1961).

TRICHLOROVINYLSILANE $Si(CH_2{=}CH)Cl_3$

Water	Vinyl trichloro silane reacts violently with water or moist air.
	Title 46 (1970).

TRIDECANAL $C_{12}H_{25}CHO$

Air	Tridecyl aldehyde is spontaneously flammable in air.
	A.B. Steele and J.J. Duggan, *Chem. Eng.* **66:** 160 (April 1969).

TRIETHYLALUMINUM $Al(C_2H_5)_3$

Air	Triethyl aluminum is spontaneously flammable in air and explodes violently in water.
	Von Schwartz, p. 321 (1918). *Kirk and Othmer, Second Ed.* **2:** 38 (1963). *MCA Case History* **819** (1962).
Carbon Tetrachloride	When mixtures of triethyl aluminum sesquichlorides in carbon tetrachloride that had been prepared with ice cooling were permitted to warm to room temperature, they first darkened, then exploded violently. The reaction is believed due to increased concentration of aluminum triethyl, which subsequently reacted with the carbon

	tetrachloride.
	H. Reinheckel, *Angew. Chem. Inter. Ed. Engl.* **3:** 65 (1964).
Dimethylformamide	See DIMETHYLFORMAMIDE plus Triethyl Aluminum.
Halogenated Hydrocarbons	Violent reactions may occur when aluminum alkyls are exposed to halogenated hydrocarbons.
	Kirk and Othmer, *Second Ed.* **2:** 38 (1963).
Triethyl Borine and Air	A mixture of 15% triethyl aluminum and 85% triethyl borine is pyrophoric.
	Rocketdyne Rept., Hypergol, p. 3 (1961).
Water	See TRIETHYL ALUMINUM plus Air.

TRIETHYLALUMINUM DIETHYL ETHERATE

$4(C_2H_5)_3Al \cdot 3(C_2H_5)_2O$

Diethyl Ether and Air	A mixture of triethyl aluminum diethyl etherate and diethyl ether is spontaneously flammable in air.
	Douda (1966).

TRIETHYL ALUMINUM SESQUICHLORIDE

(See TRICHLOROTRIETHYLDIALUMINUM)

TRIETHYL ANTIMONY

(See TRIETHYLSTIBINE)

TRIETHYLARSINE $As(C_2H_5)_3$

Air	Triethyl arsine is spontaneously flammable in air.
	Von Schwartz, p. 322 (1918).

TRIETHYLBISMUTHINE $(C_2H_5)_3Bi$

Air	Triethyl bismuthine is spontaneously flammable in air.
	Ellern, pp. 24-25 (1968).

TRIETHYLBORANE $(C_2H_5)_3B$

Air	Triethyl borine is spontaneously flammable in air.
	Douda (1966). *Ripley* (1966).
Triethyl Aluminum and Air	See TRIETHYL ALUMINUM plus Triethyl Borine and Air.

TRIETHYLDIBORANE $(C_2H_5)_3B_2H_3$

Air	Triethyl diborane is spontaneously flammable in air.
	Douda (1966).

TRIETHYL ETHOXY DIPHOSPHINYL OXIDE

$(C_2H_5)_2POP(C_2H_5)(OC_2H_5)$

Air	Triethyl ethoxy diphosphinyl oxide is spontaneously flammable in air.
	Kaufman (1961).

TRIETHYLGALLIUM $(C_2H_5)_3Ga$

Air	Triethyl gallium is spontaneously flammable in air.
	Ellern, pp. 24-25 (1968).

TRIETHYLINDIUM $(C_2H_5)_3In$

Air	Triethyl indium is spontaneously flammable in air.
	Douda (1966).

TRIETHYLSTIBINE $Sb(C_2H_5)_3$

Air	Triethyl antimony is spontaneously flammable in air. *Von Schwartz,* p. 322 (1918).

TRIETHYLSTIBINE SULFATE $Sb(C_2H_5)_3SO_4$

Air	Triethyl antimony sulfate is spontaneously flammable in air. *Bahme,* p. 25 (1961).

(TRIFLUOROMETHYL) PHOSPHINE F_3CPH_2

Air	Trifluoromethyl phosphine is spontaneously flammable in air. *Douda* (1966).

TRIFLUORONITROANILINE $F_3C_6H(NO_2)N{=}NOH$

(self-reactive)	The recrystallized compound, which had been made from trifluoronitroaniline, hydrochloric acid and sodium nitrite, exploded violently on impact. *MCA Guide for Safety,* Appendix 3 (1972).

TRIFLUOROPROPYL METHYL POLYSILOXANE

(See METHYL (TRIFLUOROPROPYL) POLYSILOXANE)

TRIHYDRAZINOCADMIUM CHLORATE $Cd(N_2H_4)_3(ClO_3)_2$

(See CADMIUM-TRIHYDRAZINE CHLORATE)

TRIHYDRAZINOCADMIUM PERCHLORATE

$Cd(H_2NNH_2)_3(ClO_4)_2Cd$

(See CADMIUM-TRIHYDRAZINE PERCHLORATE)

TRIHYDRAZINOCOBALTOUS CHLORATE $CO(N_2H_4)_3(ClO_3)_2$

(See COBALTOUS-TRIHYDRAZINE CHLORATE)

TRIHYDRAZINONICKEL CHLORATE $Ni(N_2H_4)_3(ClO_3)_2$

(See NICKEL-TRIHYDRAZINE CHLORATE)

TRIHYDRAZINONICKEL NITRATE $Ni(NO_3).3H_2NNH_2$

(See NICKEL-TRIHYDRAZINE NITRATE)

TRIISOBUTYLALUMINUM $(CH_3CHCH_3CH_2)_3Al$

Acids	Tri-iso-butyl aluminum reacts violently with acids, alcohols, amines, halogens, and water.
	Rose (1961).
Air	Tri-iso-butyl aluminum is spontaneously flammable in air.
	Rose (1961).
Alcohols	See TRI-iso-BUTYL ALUMINUM plus Acids.
Amines	See TRI-iso-BUTYL ALUMINUM plus Acids.
Halogens	See TRI-iso-BUTYL ALUMINUM plus Acids.
Water	See TRI-iso-BUTYL ALUMINUM plus Acids.

TRIMANGANESE TETROXIDE Mn_3O_4

Fluorine	See FLUORINE plus Trimanganese Tetroxide.

TRIMETHYLALUMINUM $Al(CH_3)_3$

Air	Trimethyl aluminum is spontaneously flammable in air and explodes violently in water. *Von Schwartz,* p. 321 (1918).
Halogenated Hydrocarbons	See TRIETHYL ALUMINUM plus Halogenated Hydrocarbons.
Water	See TRIMETHYL ALUMINUM plus Air.

TRIMETHYL ALUMINUM BROMIDE

(See DIBROMOTRIMETHYLALUMINUM)

TRIMETHYLALUMINUM DIETHYL ETHERATE

$(CH_3)_3Al{\bullet}(C_2H_5)_2O$

Diethyl Ether	A mixture of trimethyl aluminum diethyl
and Air	etherate and diethyl ether is spontaneously flammable in air. *Douda* (1966).

TRIMETHYLALUMINUM DIMETHYL ETHERATE

$(CH_3)_3Al{\bullet}(CH_3)_2O$

Air	Trimethyl aluminum dimethyl etherate is spontaneously flammable in air. *Douda* (1966).

TRIMETHYLAMINE OXIDE PERCHLORATE $(CH_3)_3NO{\bullet}HClO_4$

(self-reactive)	Trimethylamine oxide perchlorate explodes when heated or struck. *ACS* **146:** 213. *Berichte* **43:** 2624-30 (1910).

TRIMETHYL ANTIMONY

(See TRIMETHYLSTIBINE)

TRIMETHYL ANTIMONY SULFATE

(See TRIMETHYLSTIBINE SULFATE)

TRIMETHYL ARSENIC

(See TRIMETHYLARSINE)

TRIMETHYLARSINE $As(CH_3)_3$

Air	Trimethyl arsenic is spontaneously flammable in air. *Von Schwartz,* p. 322 (1918).

TRIMETHYLBISMUTHINE $(CH_3)_3Bi$

Air	Trimethyl bismuthine is spontaneously flammable in air. *Coates,* p. 161 (1956).

TRIMETHYLBORANE $B(CH_3)_3$

Air	Trimethyl borine is spontaneously flammable in air. *Douda* (1966).

TRIMETHYL CHLOROSILANE

(See CHLOROTRIMETHYLSILANE)

TRIMETHYLDIALUMINUM HYDRIDE $(CH_3)_2HAl_2H_2CH_3$

Water	Trimethyl dialuminum hydride reacts vigorously with water yielding methane and hydrogen, which ignite spontaneously.

Hurd, p. 98 (1952).

TRIMETHYLDIBORANE $(CH_3)_3B_2H_3$

Air	Trimethyl diborane is spontaneously flammable in air.
	Lehman and Wilson, p. 53 (1949).

TRIMETHYLGALLIUM $(CH_3)_3Ga$

Air	Trimethyl gallium is spontaneously flammable in air.
	Douda (1966).

TRIMETHYLPHOSPHINE $(CH_3)_3P$

Air	Trimethyl phosphine ignites spontaneously and burns violently in air.
	R.A. Zingaro and R.E. McGlothlin, *J. Chem. Eng. Data* **8** (2): 227 (1963).

TRIMETHYL PHOSPHITE $(CH_3O)_3P$

Magnesium Perchlorate	See MAGNESIUM PERCHLORATE plus Trimethyl Phosphite.

TRIMETHYLSTIBINE $Sb(CH_3)_3$

Air	Trimethyl antimony is spontaneously flammable in air.
	Von Schwartz, p. 322 (1918).

TRIMETHYLSTIBINE SULFATE $(CH_3)_3SbSO_4$

Air	Trimethyl antimony sulfate is spontaneously flammable in air.

Bahme, p. 25 (1961).

TRIMETHYLTHALLIUM $(CH_3)_3Tl$

Air — Trimethyl thallium is spontaneously flammable in air.

Douda (1966).

TRINITROETHANOL $(NO_2)_3CCH_2OH$

(self-reactive) — Explosions were encountered during the distillation of trinitroethanol.

J. Am. Chem. Soc. **72:** 5329 (1950).

TRINITROMETHANE $(NO_2)_3CH$

(self-reactive) — Explosions were encountered during the distillation of trinitromethane.

J. Am. Chem. Soc. **72:** 5329 (1950).

See also NITRIC ACID plus Acetylene.

TRIPHENYLALUMINUM $(C_6H_5)_3Al$

Water — Triphenyl aluminum reacts explosively with water.

Rose (1961).

TRIPHENYL TUNGSTEN-TRIS(PHENYL LITHIUM)-TRI-(DIETHYL) ETHER)

(See LITHIUM HEXAPHENYLTUNGSTATE ETHERATE)

TRIPROPYLALUMINUM $Al(C_3H_7)_3$

Air — Tripropyl aluminum is spontaneously flammable in air and explodes violently in water.

	Von Schwartz, p. 321 (1918).
Halogenated Hydrocarbons	See TRIETHYL ALUMINUM plus Halogenated Hydrocarbons.
Water	See TRIPROPYL ALUMINUM plus Air.

TRIPROPYL ANTIMONY

(See TRIPROPYLSTIBINE)

TRIPROPYLBORANE $(C_3H_7)_3B$

Air	Tripropylborane is spontaneously flammable in air.
	Douda (1966).

TRIPROPYLINDIUM $(C_3H_7)_3In$

Air	Tripropyl indium is spontaneously flammable in air.
	Douda (1966).

TRIPROPYLSTIBINE $(C_3H_7)_3Sb$

Air	Tripropyl antimony is spontaneously flammable in air.
	Ellern, pp. 24-25 (1968).

TRISILANE Si_3H_8

Air	In air, trisilane and tetrasilane explode. See also SILANES plus Air.
	Mellor **6:** 224 (1946-1947).
Carbon Tetrachloride	Carbon tetrachloride reacts more vigorously on trisilane and tetrasilane than on disilane.
	Mellor **6:** 224 (1946-1947).

Oxygen	See OXYGEN plus Disilane.

TRISILYLAMINE $(SiH_3)_3N$

Air	Trisilylamine is spontaneously flammable in air.
	Mellor **8:** 262 (1946-1947).

TRISILYLARSINE $(SiH_3)_3As$

Air	Trisilyl arsine is spontaneously flammable in air.
	Douda (1966).

TRISILYLPHOSPHINE $(SiH_3)_3P$

(self-reactive)	This is a spontaneously flammable liquid.
	Mellor **8, Supp. 3:** 283 (1971).
Air	The liquid ignites spontaneously in air.
	Ellern, p. 22 (1968). *Douda* (1966).

1,3,5-TRIS(NITROMETHYL)BENZENE $C_6H_3(CH_2NO_2)_3$

(self-reactive)	See NITRIC ACID plus Mesitylene.

TRIS(TRIFLUOROMETHYL)PHOSPHINE $(CF_3)_3P$

Air	Tristrifluoromethyl phosphine is spontaneously flammable in air.
	Douda (1966). *Handbook Chem. Phys.*, p. **C-428** (1970-1971).

TRIS(TRIMETHYLSILYL)PHOSPHINE $[(CH_3)_3Si]_3P$

Air	Tristrimethyl silyl phosphine is spontaneously flammable

	in air.
	Def. Res. and Eng., p. 247 (1963).

TRITOLYLAMINE PERCHLORATE $(CH_3C_4H_6)_3NHClO_4$

(self-reactive)	Tritolylamine perchlorate explodes above 123¡C.
	ACS **146:** 213. *Berichte* **43:** 2624-30 (1910).

TRIVINYL ANTIMONY $(CH_2{=}CH)_3Sb$

Air	Trivinyl antimony is spontaneously flammable in air.
	Zeiss, p. 92 (1960).

TRIVINYLBISMUTHINE $(CH_2{=}CH)_3Bi$

Air	Trivinyl bismuthine is spontaneously flammable in air.
	Zeiss, p. 129 (1960).

TROPYLIUM PERCHLORATE $(C_7H_7)ClO_4$

(self-reactive)	An 80-gram sample of tropylium perchlorate heaped in a transfer funnel exploded violently when it was touched by a glass rod.
	Angew. Chem. Intern. Ed. Engl. **1** (7): **465** (1962).

TUNGSTEN W

Bromine Trifluoride	See MOLYBDENUM plus Bromine Trifluoride.
Chlorine Trifluoride	See ANTIMONY plus Chlorine Trifluoride.
Fluorine	See FLUORINE plus Tungsten.
Iodine Pentafluoride	See ARSENIC plus Iodine Pentafluoride.
Lead Dioxide	See MOLYBDENUM plus Lead Dioxide.

TUNGSTEN CARBIDE WC

Chlorine Trifluoride	See CHLORINE TRIFLUORIDE plus Mercuric Iodide.
Fluorine	See FLUORINE plus Tungsten Carbide.
Nitrogen Dioxide	Tungsten carbide burns with incandescence if heated to dull redness in either nitrous oxide or nitrogen dioxide.
	Mellor **5:** 890 (1946-1947).
Nitrous Oxide	See TUNGSTEN CARBIDE plus Nitrogen Dioxide.

TUNGSTEN DIOXIDE WO_2

Chlorine	See CHLORINE plus Tungsten Dioxide.

TUNGSTEN TRIOXIDE WO_3

Chlorine Trifluoride	The reaction between tungsten trioxide and chlorine trifluoride is accompanied by incandescence.
	Mellor **11:** 730 (1946-1947).
	See also CHLORINE TRIFLUORIDE plus Aluminum Oxide.
Lithium	See LITHIUM plus Tungsten Trioxide.

TURPENTINE

Calcium Hypochlorite	See CALCIUM HYPOCHLORITE plus Turpentine.
Chlorine	See CHLORINE plus Hydrocarbons.
Chromic Anhydride	See CHROMIC ANHYDRIDE plus Naphthalene.
Chromyl Chloride	See CHROMYL CHLORIDE plus Acetone.
Hexachloromelamine	See HEXACHLOROMELAMINE plus Organic Contaminants.
Stannic Chloride	See STANNIC CHLORIDE plus Turpentine.
Trichloromelamine	See HEXACHLOROMELAMINE plus Organic

	Contaminants.

TYGON□

Fluorine	See FLUORINE plus Solid Nonmetals and Oxygen.

UNSYMMETRICAL DIMETHYLHYDRAZINE

(See uns-DIMETHYLHYDRAZINE)

URANIUM U

Air	Clean uranium turnings or chips oxidize readily in air. If confined in a container without air movement, they can ignite spontaneously. Moisture increases this reactivity.
	Scott (1970).
Carbon Tetrachloride	An explosion occurred when liquid carbon tetrachloride was used in an attempt to extinguish a small fire involving about a half pound of uranium.
	Allison (1969).
Chlorine	See CHLORINE plus Uranium.
Fluorine	See FLUORINE plus Uranium.
Nitric Acid	Nitric acid can react with uranium with explosive violence.
	Katz and Rabinowitch (1951).
	Freshly cleaned uranium turnings in a stainless steel beaker were covered with hot water and nitric acid to bring the concentration to 4 to 6 normal. When cold rinse water was turned on, an explosion accompanied by a flash, ejected the turnings from the beaker.
	Serious Acc. Series **250** (1965).
Nitric Oxide	Uranium ignites in warm nitric oxide.
	Mellor **12:** 31-2 (1946-1947).
Selenium	Uranium reacts with incandescence with hot selenium or sulfur (boiling).

	Mellor **12:** 31-2 (1946-1947).
Sulfur	See URANIUM plus Selenium.
Water	Uranium turnings and fines stored out of doors in a closed container under water or water-soluble oil will hydride and eventually ignite during hot weather.
	Scott (1970).

URANIUM BOROHYDRIDE

(See URANIUM TETRAHYDROBORATE)

URANIUM CARBIDE

(See URANIUM DICARBIDE)

URANIUM DICARBIDE UC_2

Air	Uranium dicarbide ignites if powdered in a mortar.
	Mellor **5:** 890 (1946-1947).
Bromine	See BROMINE plus Uranium Dicarbide.
Chlorine	See BROMINE plus Uranium Dicarbide.
Fluorine	See BROMINE plus Uranium Dicarbide.
Water	Uranium dicarbide (at dull-red heat) reacts with steam with incandescence.
	Mellor **5:** 890 (1946-1947).

URANIUM DIOXIDE UO_2

Air	Uranium oxide is spontaneously flammable in air.
	Brauer (1965).

URANIUM HYDRIDE UH_3

Air	Uranium hydride is spontaneously flammable in air.
	J. Zehr, *Staub* **22** (11): 494-508 (1962). *Brauer* (1965).

URANIUM-NEODYMIUM ALLOY

Nitric Acid	Explosive or violent reactions have occurred during or subsequent to pickling of the alloy with nitric acid.
	Allison (1969).

URANIUM-NEODYMIUM-ZIRCONIUM ALLOY

Nitric Acid	Explosive or violent reactions have occurred during or subsequent to pickling of the alloy with nitric acid.
	Allison (1969).

URANIUM NITRIDE UN

Air	Uranium nitride is spontaneously flammable in air.
	J. Zehr, *Staub* **22** (11): 494-508 (1962).

URANIUM OXIDES UO_2;UO_3;U_3O_8

Bromine Trifluoride	See BROMINE TRIFLUORIDE plus Uranium Oxides.

URANIUM PHOSPHIDE U_3P_4

Hydrochloric Acid	Uranium phosphide reacts with hydrochloric acid to release spontaneously flammable phosphine.
	Mellor **8, Supp. 3:** 349 (1971).

URANIUM TETRAHYDROBORATE $U(BH_4)_3$

Air	Uranium borohydride is spontaneously flammable in air.
	H.I. Schlesinger et al, *J. Am. Chem. Soc.* **75:** 219-223

(1953).

URANYL PERCHLORATE $UO_2(ClO_4)_2$

Ethyl Alcohol	Attempts at recrystallization from ethyl alcohol resulted in an explosion. *Mellor* **2, Supp. 1:** 617 (1956).

p-URAZINE

(self-reactive)	While a chemist was manipulating the material in a glass container, an explosion occurred that shattered the container. The material that exploded was probably a nitrogen-containing byproduct. *MCA Case History* **144** (1966).

UREA $(NH_2)_2CO$

Gallium Perchlorate	See GALLIUM PERCHLORATE plus Urea.
Hypochlorites	See HYPOCHLORITES plus Urea.

VANADIUM V

Bromine Trifluoride	See MOLYBDENUM plus Bromine Trifluoride.
Chlorine	See CHLORINE plus Vanadium.
Lithium	See LITHIUM plus Vanadium.

VANADIUM OXYDICHLORIDE $VOCl_2$

Potassium	See POTASSIUM plus Boric Acid.

VANADIUM OXYTRICHLORIDE $VOCl_3$

Phosphorus	See PHOSPHORUS plus Vanadium Oxytrichloride.

VANADIUM PENTACHLORIDE VCl_5

Potassium	See POTASSIUM plus Aluminum Bromide.
Sodium	See SODIUM plus Aluminum Bromide.

VANADIUM PENTOXIDE V_2O_5

Calcium, Sulfur and Water	See CALCIUM plus Vanadium Oxide, Sulfur, and Water.
Chlorine Trifluoride	See CHLORINE TRIFLUORIDE plus Aluminum Oxide.
Lithium	See LITHIUM plus Vanadium Pentoxide.

VANADIUM SESQUIOXIDE V_2O_3

Air	Vanadium sesquioxide is spontaneously flammable in air. *Ellern* (1961).

VANILLIN $CH_3O(HO)C_6H_3CHO$

Thallium Trinitrate Trihydrate and Formic Acid	See THALLIUM TRINITRATE TRIHYDRATE plus Formic Acid and Vanillin.

VEGETABLE GLUES

Aluminum	See ALUMINUM plus Nitrates.

VINYL ACETATE $CH_2{=}CHOCOCH_3$

2-Aminoethanol	See 2-AMINOETHANOL plus Vinyl Acetate.
Chlorosulfonic Acid	Mixing vinyl acetate and chlorosulfonic acid in a closed container caused the temperature and pressure to increase. *Flynn and Rossow* (1970). See Note under complete reference.
Ethylene Diamine	See ETHYLENE DIAMINE plus Vinyl Acetate.
Ethyleneimine	Mixing vinyl acetate and ethyleneimine in a closed container caused the temperature and pressure to increase. *Flynn and Rossow* (1970). See Note under complete reference.
Hydrochloric Acid	Mixing vinyl acetate and 36% hydrochloric acid in a closed container caused the temperature and pressure to increase. *Flynn and Rossow* (1970). See Note under complete reference.
Hydrofluoric Acid	Mixing vinyl acetate and 48.7% hydrofluoric acid in a closed container caused the temperature and pressure to increase. *Flynn and Rossow* (1970). See Note under complete reference.
Nitric Acid	Mixing vinyl acetate and 70% nitric acid in a closed container caused the temperature and pressure to increase. *Flynn and Rossow* (1970). See Note under complete reference.
Oleum	See OLEUM plus Vinyl Acetate.
Peroxides	Vinyl acetate in contact with peroxides may polymerize violently. *Haz. Chem. Data* (1966).
Sulfuric Acid	Mixing vinyl acetate and 96% sulfuric acid in a closed container caused the temperature and pressure to increase. *Flynn and Rossow* (1970). See Note under complete reference.

VINYL ACETATE-CHLORIDE COPOLYMER

Fluorine	See FLUORINE plus Solid Nonmetals and Oxygen.

VINYL AZIDE $CH_2{=}CHN_3$

(self-reactive)	A sample of vinyl azide in a distilling flask with a ground glass joint exploded when the joint was rotated.
	R.H. Wiley and J. Moffat, *J. Org. Chem.* **22:** 995 (1957).

VINYL CHLORIDE $CH_2{=}CHCl$

Air	An unstable polyperoxide is apparently formed in vinyl chloride through oxidation by atmospheric oxygen in the presence of any of a variety of contaminants. Storage under these conditions for a long period increases the concentration of unstable polyperoxide to hazardous levels.
	MCA Case History **1551** (1969).

VINYLIDENE CHLORIDE $CH_2{=}CCl_2$

(self-reactive)	A coating of vinylidene chloride polymer on the inside of a 2-inch pipe exploded when the pipe touched a fitting on a tank car.
	MCA Case History **1172** (1966).
Chlorosulfonic Acid	Mixing vinylidene chloride and chlorosulfonic acid in a closed container caused the temperature and pressure to increase.
	Flynn and Rossow (1970). See Note under complete reference.
Nitric Acid	Mixing vinylidene chloride and 70% nitric acid in a closed container caused the temperature and pressure to increase.
	Flynn and Rossow (1970). See Note under complete reference.

Oleum	See OLEUM plus Vinylidene Chloride.

VINYL TRICHLORO SILANE

(See TRICHLOROVINYLSILANE)

VITON A□

Fluorine	See FLUORINE plus Solid Nonmetals and Oxygen.

WAX, DRAWING

Chlorine	See CHLORINE plus Polypropylene.

XANTHATES

Diazonium Salts	See DIAZONIUM SALTS plus Thiophenates.

XENON HEXAFLUORIDE XeF_6

Water	Xenon hexafluoride reacted with water to form explosive xenon trioxide. *Health & Safety Inf.* **181** (1964). *Chem. Eng. News* **13:** 45-6 (1963). *J. Am. Chem. Soc.* **85:** 816 (1963).

2(X, Y-XYLYL)ETHANOL $(CH_3)_2C_6H_3CH_2CH_2OH$

Hydrogen Peroxide and Sulfuric Acid	See ALCOHOLS plus Hydrogen Peroxide and Sulfuric Acid.

YTTERBIUM Yb

Air	See RARE EARTH METALS plus Air.
Halogens	See RARE EARTH METALS plus Halogens.

YTTRIUM Yt

Air	See RARE EARTH METALS plus Air.
Halogens	See RARE EARTH METALS plus Halogens.

ZIEGLER-TYPE CATALYSTS

Allyl Chloride	See SULFURIC ACID plus Allyl Chloride.

ZINC Zn

Acids	Zinc powder or dust in contact with acids evolves hydrogen. The heat of reaction is sufficient that the hydrogen may ignite. *Lab. Govt. Chemist* (1965).
Ammonium Nitrate	The two substances are mixed intimately and wetted with 3 or 4 drops of water. After a short time, a violent reaction occurs with evolution of steam and zinc oxide. *Greaves* (1967). *Mellor* **8, Supp. 1:** 546 (1964). See also AMMONIUM NITRATE plus Metals (powdered).
Barium Dioxide	See MAGNESIUM plus Barium Nitrate, Barium Dioxide and Zinc.
Barium Nitrate	See MAGNESIUM plus Barium Nitrate, Barium Dioxide and Zinc.
Cadmium	See ZINC plus Selenium.
Carbon Disulfide	A mixture of zinc and carbon disulfide reacts with incandescence. *Mellor* **4:** 476-90 (1946-1947).
Chlorates	A mixture of powdered zinc and an oxidizing agent such as potassium chlorate can be exploded by percussion. *Mellor* **4:** 480 (1946-1947).

Chlorine	Zinc burns in moist chlorine.
	Mellor **4:** 476 (1946-1947).
Chlorine Trifluoride	See ALUMINUM plus Chlorine Trifluoride.
Chromic Anhydride	A violent reaction or flaming is likely in the reaction of chromic anhydride and zinc dust.
	Mellor **11:** 237 (1946-1947).
Ethyl Acetoacetate and Tribromoneopentyl Alcohol	See ETHYL ACETOACETATE plus Tribromoneopentyl and Zinc.
Fluorine	See FLUORINE plus Zinc.
Hydrazine Mononitrate	When hydrazine mononitrate is heated in contact with zinc, copper and most other metals as well as oxides, sulfides, nitrides and carbides, a flaming decomposition occurs at temperatures a little above its melting point.
	Mellor **8:** 327 (1946-1947).
Hydroxylamine	Hydroxylamine is reduced when heated with zinc dust; sometimes the mixture merely ignites; other times, it explodes.
	Mellor **8:** 290 (1946-1947).
Lead Azide	See COPPER plus Lead Azide.
Magnesium, Barium Nitrate and Barium Dioxide	See MAGNESIUM plus Barium Nitrate, Barium Dioxide and Zinc.
Manganese Chloride	Zinc powder reacts explosively when heated with manganese chloride.
	Mellor **4:** 479 (1946-1947).
Nitric Acid	When concentrated nitric acid is poured on molten zinc, the reaction proceeds with incandescence.
	Mellor **4:** 476-90 (1946-1947).
Performic Acid	Powdered zinc can decompose performic acid violently, causing an explosion.

	Berichte **48:** 1139 (1915).
Potassium Chlorate	See ZINC plus Chlorates.
Potassium Nitrate	Powdered zinc and potassium nitrate explode if heated.
	Mellor **7:** 116 (1946-1947).
Potassium Peroxide	See POTASSIUM plus Potassium Peroxide.
Selenium	The reaction between zinc and selenium or tellurium is accompanied by incandescence (cadmium less so).
	Mellor **4:** 480 (1946-1947).
Sodium Chlorate	See ZINC plus Chlorates.
Sodium Peroxide	Sodium peroxide oxidizes zinc with incandescence.
	Mellor **2:** 490-93 (1946-1947).
Sulfur	See SULFUR plus Zinc.
Tellurium	See ZINC plus Selenium.
Water	Zinc powder or dust in contact with water or damp air evolves hydrogen. The heat of reaction is sufficient that the hydrogen may ignite.
	Haz. Chem. Data p. 171 (1966).
	Lab. Govt. Chemist (1965).
Zinc Peroxide	See ALUMINUM plus Zinc Peroxide.

ZINC AMIDE $Zn(NH_2)_2$

Hydrazine	The action of an ethereal solution of hydrazine on zinc diamide or diethyl zinc, gives a product, zinc hydrazine, which explodes at 70¡C.
	Mellor **8:** 315 (1946-1947).

ZINC BENZENEDIAZONIUM CHLORIDE $C_6H_5\text{-}N{=}NClZnCl_2$

(self-reactive)	Zinc benzenediazonium chloride had been washed in dry acetone and had been stored in a vacuum desiccator 15 hours when it exploded.

	Chem. & Ind. p. 58-9 (1956).

ZINC BROMATE $Zn(BrO_3)_2$

Aluminum	See ALUMINUM plus Bromates.
Arsenic	See ARSENIC plus Bromates.
Carbon	See CARBON plus Bromates.
Copper	See COPPER plus Bromates.
Metal Sulfides	See METAL SULFIDES plus Bromates.
Organic Matter	See BROMATES plus Organic Matter.
Phosphorus	See PHOSPHORUS plus Bromates.
Sulfur	See SULFUR plus Bromates.

ZINC BROMIDE $ZnBr_2$

Potassium	See POTASSIUM plus Aluminum Bromide.
Sodium	See SODIUM plus Aluminum Bromide.

ZINC CHLORATE $Zn(ClO_3)_2$

Aluminum	See ALUMINUM plus Bromates.
Antimony Sulfide	See CHLORATES plus Antimony Sulfide. See also METAL SULFIDES plus Bromates.
Arsenic	See ARSENIC plus Bromates.
Arsenic Sulfide	See CHLORATES plus Arsenic Sulfide. See also METAL SULFIDES plus Bromates.
Carbon	See CARBON plus Bromates.
Charcoal	Zinc chlorate and charcoal (or finely divided organic matter) form mixtures which may ignite or explode. Such ignition or explosion may be caused by friction, percussion, or shock. *U.S. Army Ord. Safety Man.* (1951).

	See also CHLORATES plus Organic Matter.
Copper	See COPPER plus Bromates.
Copper Sulfide	See COPPER SULFIDE plus Cadmium Chlorate.
Manganese Dioxide	See CHLORATES plus Manganese Dioxide.
Metal Sulfides	See METAL SULFIDES plus Bromates.
Organic Acids (Dibasic)	See CHLORATES plus Organic Acids.
Organic Matter	See ZINC CHLORATE plus Charcoal. See ALUMINUM plus Bromates.
	See CHLORATES plus Organic Matter.
Phosphorus	See PHOSPHORUS plus Bromates.
Stannic Sulfide	See STANNIC SULFIDE plus Cadmium Chlorate. See METAL SULFIDES plus Bromates.
Stannous Sulfide	See STANNOUS SULFIDE plus Cadmium Chlorate. See METAL SULFIDES plus Bromates.
Sulfur	See SULFUR plus Bromates. See CHLORATES plus Organic Matter.
Sulfuric Acid	Zinc chlorate in contact with concentrated sulfuric acid is likely to cause fires and explosions.
	Bahme, p. 29 (1961).
	See CHLORATES plus Acids.

ZINC CHLORIDE $ZnCl_2$

Potassium	See POTASSIUM plus Aluminum Bromide.

ZINC CYANIDE $Zn(CN)_2$

Magnesium	See MAGNESIUM plus Cadmium Cyanide.

ZINC DIALKYLS

Air	These compounds are spontaneously flammable in air.

	Von Schwartz, p. 329 (1918).

ZINC DIETHYL

(See DIETHYL ZINC)

ZINC DIPROPYL $(C_3H_7)_2Zn$

(See DIPROPYL ZINC)

ZINC DIVINYL $(CH_2CH)_2Zn$

(See DIVINYL ZINC)

ZINC FLUORIDE ZnF_2

Potassium	See POTASSIUM plus Ammonium Bromide.

ZINC-HYDRAZINE CHLORATE

(self-reactive)	This compound detonates when struck but is less sensitive than tetramminiozinc chlorate. *Mellor* **2, Supp. 1:** 592 (1956).

ZINC IODATE $Zn(IO_3)_2$

Aluminum	See ALUMINUM plus Bromates.
Arsenic	See ARSENIC plus Bromates.
Carbon	See CARBON plus Bromates.

ZINC IODIDE ZI_2

Potassium	See POTASSIUM plus Alumium Bromide.

ZINC NITRATE $Zn(NO_3)_2$

Carbon	See CARBON plus Zinc Nitrate.
Copper	See COPPER plus Bromates.
Metal Sulfides	See METAL SULFIDES plus Bromates.
Organic Matter	See BROMATES plus Organic Matter.
Phosphorus	See PHOSPHORUS plus Bromates.
Sulfur	See SULFUR plus Bromates.

ZINC OXIDE ZnO

Chlorinated Rubber	Reaction between zinc oxide and chlorinated rubber in a large batch resulted in a violent explosion that wrecked a manufacturing building. *Chem. Eng. News* **40** (36): 79 (1962).
Magnesium	See MAGNESIUM plus Beryllium Oxide.

ZINC PEROXIDE ZnO_2

Aluminum	See ALUMINUM plus Zinc Peroxide.
Zinc	See ALUMINUM plus Zinc Peroxide.

ZINC PHOSPHIDE Zn_3P_2

Water	Moisture reacts with zinc phosphide with production of phosphine, a spontaneously flammable gas. *Oldbury Chemicals.*

ZINC SULFIDE ZnS

Iodine Monochloride	See IODINE MONOCHLORIDE plus Cadmium Sulfide.

ZINC-TETRAMMINE CHLORATE $Zn(NH_3)_4(ClO_3)_2$

(self-reactive)	This compound detonates when struck.
	Mellor **2, Supp. 1:** 592 (1956).

ZINC-TETRAMMINE PERCHLORATE $Zn(NH_3)_4(ClO_4)_2$

(self-reactive)	This compound detonates when struck but is less sensitive than tetramminiozine chlorate.
	Mellor **2, Supp. 1:** 592 (1956).

ZIRCONIUM Zr

Air	See TANTALUM plus Air.
Alkali Hydroxides	When a mixture of alkali hydroxide and zirconium is heated, the liberated oxygen reacts explosively with the zirconium.
	Mellor **7:** 116 (1946-1947).
Alkali Metal Chromates	See ZIRCONIUM plus Alkali Metal Salts.
Alkali Metal Dichromates	See ZIRCONIUM plus Alkali Metal Salts.
Alkali Metal Molybdates	See ZIRCONIUM plus Alkali Metal Salts.
Alkali Metal Salts	Chromates, dichromates, sulfates, molybdates and tungstates of lithium, sodium, potassium, rubidium and cesium will react violently, even explosively, with an excess of zirconium powder and yield the impure metal.
	Ellern, p. 249 (1968). *Mellor* **2: Supp. II and III.**
Alkali Metal Sulfates	See ZIRCONIUM plus Alkali Metal Salts
Alkali Metal Tungstates	See ZIRCONIUM plus Alkali Metal Salts.

Borax	A mixture of hydrated borax and zirconium explodes when heated. *Mellor* **7:** 116 (1946-1947).
Carbon Tetrachloride	An explosion occurred when zirconium sponge was placed in a beaker of carbon tetrachloride. *Allison* (1969).
Cupric Oxide	Zirconium explodes violently with cupric oxide or lead oxide. *Mellor* **7:** 116 (1946-1947).
Lead	See LEAD plus Zirconium.
Lead Oxide	See ZIRCONIUM plus Cupric Oxide.
Phosphorus	See PHOSPHORUS plus Zirconium.
Potassium Chlorate	When heated, potassium chlorate reacts with zirconium with slight explosions. *Mellor* **7:** 116 (1946-1947).
Potassium Nitrate	A mixture of powdered zirconium and potassium nitrate explodes when heated above the melting temperature. *Mellor* **7:** 116 (1946-1947).

ZIRCONIUM BOROHYDRIDE

(See ZIRCONIUM TETRAHYDROBORATE)

ZIRCONIUM CARBIDE ZrC

Air	Zirconium carbide in the form of a fine powder is spontaneously flammable in air. *Rose* (1961).

ZIRCONIUM DIBROMIDE $ZrBr_2$

Air	Zirconium dibromide is spontaneously flammable in air.

Douda (1966).

ZIRCONIUM DICARBIDE ZrC_2

Bromine	See BROMINE plus Zirconium Dicarbide.
Chlorine	See BROMINE plus Zirconium Dicarbide.
Fluorine	See BROMINE plus Zirconium Dicarbide.
Iodine	See BROMINE plus Zirconium Dicarbide.

ZIRCONIUM DIHYDRIDE ZrH_2

Air — When heated in air, zirconium dihydride burns with incandescence.

Mellor **7:** 116 (1946-1947).

ZIRCONIUM TETRACHLORIDE $ZrCl_4$

Lithium — See LITHIUM plus Chromium Trichloride.

ZIRCONIUM TETRAHYDROBORATE $Zr(BH_4)_4$

Air — Zirconium borohydride is spontaneously flammable in air.

Gaylord, p. 58 (1956).

ZIRCONIUM-URANIUM ALLOY

Nitric Acid — Contact of etched or cleaned zirconium-uranium alloy with nitric acid results in a mild explosion.

Allison (1969).

REFERENCES

Abbey — *Communication*, D.R. Abbey, Don Mills, Ontario

Acad. Handl.	*K. Krigs Vetenskaps Akadamien,* Stockholm, Handlingar
Acc. Chem. Res.	*Accounts of Chemical Research,* American Chemical Society, Washington, D.C.
Acc. & Fire Prev. Inf.	*Accident and Fire Prevention Information,* U.S. Atomic Energy Commission, Washington, D.C.
ACS 15 (1923)	*ACS Monograph 15,* "Organic Arsenical Compounds," G.W. Raizisc and J.L. Gavron, The Chemical Catalog Co., New York (1923)
ACS 146	*ACS Monograph 146,* "Perchlorates, Their Properties, Manufacture and Uses," J.C. Schumacher, Reinhold, New York (1960)
Acta Crystallogr.	*Acta Crystallographica,* Copenhagen
AEC Research & Devel. Report	*Research and Development Reports,* U.S. Atomic Energy Commission, Oak Ridge, Tennessee
Aero. and Astro.	*Aeronautics and Astronautics,* American Institute of Aeronautics and Astronautics, Inc., New York
Aero. Tech. Note	*Aeronautics Technical Note,* National Advisory Committee, Washington, D.C.
AIChE Loss Prevention, 1967	*Loss Prevention, 1967,* F. Lorentz, American Institute of Chemical Engineers, New York (1967)
Albrecht	*Communication,* A.R. Albrecht, The Dow Chemical Company, Midland, Mich.
Allison	*Communication,* W.W. Allison, Sandia Corp., Albuquerque, N.M.
Aluminum Alkyls	*Aluminum Alkyls,* Ethyl Corporation, New York
Am. Chem. J.	*American Chemical Journal,* American Chemical Society, Washington, D.C.
Analyst	*The Analyst,* Journal of the Society for Analytical Chemistry, Cambridge, England
Angew. Chem.	*Angewandte Chemie,* Weinheim, West Germany
Angew. Chem. Intern.	*Angewandte Chemie,* International Edition in English,
Ed. Engl.	Academic Press, New York
Aniline	*Aniline,* National Aniline Division, Allied Chemical Corp.,

	New York (1964)
Ann. Chem.	*Annalen der Chemie,* Justus Liebigs, Weinheim
Ann. Chim. et Phys.	*Annales de Chimie et de Physique,* Paris
Ann. Phys.	*Annalen der Physik*, Barth, Leipzig
Arbeitsschutz	*Arbeitsschutz,* Bundesministen Fuer Arbeit and Sozialordnung, Cologne
ASESB Expl. Report	*ASESB Explosives Incident Report,* Armed Services Explosives Safety Board, Washington, D.C.
ASESB Pot. Incid.	*ASESB Potential Incident Report,* Armed Services Explosives Safety Board, Washington, D.C.
ASHREA Journal	*ASHREA Journal,* American Society of Heating, Refrigeration and Air Conditioning Engineers, New York.
Bahme	*Fire Protection for Chemicals,* C.W. Bahme, National Fire Protection Assn., Boston (1961)
Barrett	*Communication,* R.E. Barrett, Chevron Oil Field Research Company, La Holra, Calif.
Baudrimant	*Recherches sur les Clorures et les Bromures de Phosphore,* E. Baudrimant
BCISC	*Quarterly Safety Summary of the British Chemical Industry Safety Council,* Society of the Chemical Industry, London
Becker	*Communication,* E.I. Becker, American Chemical Society, Committee on Chemical Safety
Beilstein	*Handbuch der Organischen Chemie*, F. Beilstein, J. Springer Pub. (1929)
Benson	*Communication*, C. Benson, Federal Correctional Institution, La Tuna, Texas
Berichte	*Berichte der Deutschen Chemischen Gesellschaft,* Verlag Chemie, Weinheim, Germany
Bernthsen	*Textbook of Organic Chemistry,* A. Bernthsen, D. van Nostrand, New York (1912)
Berzelius	*Lehrbuch der Chemie,* J.J. Berzelius, Dresden (1825)
Bibl. Univ. Genéve	*Bibliothéque Universelle de Genéve*
Biul. Wojskowej Akad. Tech.	*Biuletyn Wojskowski Akademii Techniczenj Imeni*

	Jaroslawa Dabrowskiego, Warsaw, Poland
BM Bull.	*Bulletin*, Bureau of Mines, U.S. Department of the Interior, Washington
BM Explos. Div. Rep.	*Report of Bureau of Mines, Explosives Division*, U.S. Department of Interior, Pittsburgh, Pa.
BM Info. Circ.	*Information Circular*, Bureau of Mines, U.S. Department of Interior, Pittsburgh, Pa.
BM Report Invest.	*Report of Investigations*, Bureau of Mines, U.S. Department of the Interior, Pittsburgh, Pa.
Bozich	*Communication*, T.A. Bozich, Case Institute of Technology, Cleveland, Pittsburgh, Pa.
Brauer	*Handbook of Preparative Inorganic Chemistry*, Ed. by G. Brauer. Academic Press, New York (1965)
Brennstoff-Chem.	*Brennstoff-Chemie, Zeitschrift fuer Chemie und Tecknik von Kohle, Oel und Gas*, W. Girardet, Essen.
Bull. Acad. Belg.	*Bulletin de l'AcadŽemie de Belgique*
Bull. Acad. St. Petersburg	*AcadŽmie ImpŽriale des Sciences de St. Petersbourg*, St. Petersbourg
Bull. Soc. Chim.	*Bulletin de la SociŽtŽ Chimique de France*, Masson & Cie., Paris
Buls, Bimonthly Rept. 5	*Potential CW Agents, Task 5, Boron Compounds as Toxicants*, V.W. Buls. Bimonthly Rept. *5*, AD 46023, Shell Development Co., Emeryville, Calif. (Apr-May, 1953)
Buls, Bimonthly Rept. 6	*Potential CW Agents, Task 5, Boron Compounds as Toxicants*, V.W. Buls. Bimonthly Rept. 6, AD 46101, Shell Development Co., Emeryville, Calif. (June-July, 1953)
Buls, Bimonthly Rept. 8	*Potential CW Agents, Task 5, Boron Compounds as Toxicants*, V.W. Buls. Bimonthly Rept. 8, AD 38431, Shell Development Co., Emeryville, Calif. (Oct-Nov., 1953)
Bureau of Mines	*U.S. Bureau of Mines*, Pittsburgh, Private communication
Cady	*Communication*, E. Cady, University of Washington, Seattle, Wash.
Can. J. Chem.	*Canadian Journal of Chemistry*, National Research Council, Ottawa

Can. J. Research	*Canadian Journal of Research,* National Research Council, Ottawa
Chaney	*Communication,* L.E. Chaney, Battelle Memorial Institute, Columbus, Ohio
Chapman	*Communication,* F.F. Chapman, E.I. du Pont de Nemours & Co
F.F. Chapman	*Communication,* F.F. Chapman, Beckman Instruments, Inc., Fullerton, Calif.
Chem. Abst.	*Chemical Abstracts*, American Chemical Society, Columbus, Ohio
Chem. Age	*Chemical Age*, Benn Brothers, Ltd., London
Chem. Ber.	*Chemische Berichte,* Weinheim-Bergstr., West Germany
Chem. in Brit.	*Chemistry in Britain*, The Royal Institute of Chemistry and the Chemical Society, London
Chem. Eng. News	*Chemical and Engineering News*, American Chemical Society, Washington
Chem. Eng. Progr. Tech. Man.	*Chemical Engineering Progress Technical Manual,* "Loss Prevention", Vol. 1, American Institute of Chemical Engineers, New York
Chem. Eng. Progs.	*Chemical Engineering Progress,* American Institute of Chemical Engineers, New York
Chem. Gaz.	*Chemical Gazette*
Chem. Haz. Info. Series	*Chemical Hazards Information Series,* American Insurance Assn. (Assn. of Casualty and Surety Companies prior to January 1965), New York.
Chem. & Ind.	*Chemistry & Industry,* Society of the Chemical Industry, London
Chem. & Met. Eng.	*Chemical & Metallurgical Engineering,* New York
Chem. News	*The Chemical News and Journal of Physical Science*
Chem. Phar. Bull.	*Chemical and Pharmaceutical Bulletin,* Japan Publications Trading Co., Ltd., Tokyo
Chem. Process (Chicago)	*Chemical Processing,* Putnam Publishing Co., Chicago
Chem. Reviews	*Chemical Reviews,* American Chemical Society,

	Washington, D.C.
Chem. Safety Data Sheet	*Chemical Safety Data Sheet*, Manufacturing Chemists' Association, Inc., Washington
Chem. Weekblad	*Chemisch Weekblad*, Royal Netherlands Chemical Society, The Hague
Chem. Zentr.	*Chemisches Zentralblatt*, Akadamie-Verlag, Berlin
Chemiker Z.	*Chemiker Zeitung*, Alfred Huethig, Heidelberg
Chim. Ind. (Paris)	*Chimie & Industrie (Paris)*, Paris. English Translation: AERE Trans. 1064, R.A. Slingo, Atomic Energy Research Establishment, Harwell, England
Coates	*Organo-Metallic Compounds*, G.E. Coates, John Wiley and Sons, Inc., New York (1956)
Coffee	*Communication*, R.D. Coffee, Eastman Kodak Co., Rochester, New York
Comb. & Flame	*Combustion and Flame*, American Elsevier Publishing Co., Inc., New York
Comp. Gas Bull.	*Compressed Gas Bulletin*, Compressed Gas Assn., New York
Comp. Rend.	*Comptes Rendus Hebdomadaires des SŽances de l'AcadŽmie des Sciences*, Gauthier-Villars, Paris
Cond. Chem. Dict.	*The Condensed Chemical Dictionary*, Eighth Edition, Van Nostrand Reinhold Co., New York, N.Y., 1971
Corrosion	*Corrosion*, National Association of Corrosion Engineers, Houston
Coventry	*Communication*, C. C. Coventry, International Latex and Chemical Corp., Dover, Delaware
Crucible	*Crucible*, Pittsburgh Section, American Chemical Society
Damon	*Communication*, G. H. Damon, Bureau of Mines, U. S. Department of the Interior, Washington, D. C.
Dangerous Chem. Code	*Dangerous Chemicals Code*, Bureau of Fire Prevention, City of Los Angeles, Parker and Co., Los Angeles (1951)
Davis	*Chemistry of Powder and Explosives*, T. L. Davis, Wiley & Sons, Inc., New York (1943)

R. Davis	*Communication,* R. Davis, Essex Chemical
Dean	*Communication,* F. H. Dean, Ontario Research Department, Sheridan Park, Ontario
Def. Res. and Eng.	The Handling and Storage of Liquid Propellants, AD 442849, *Office of the Director of Defense Research and Engineering,* Washington, D. C. (Jan. 1963)
Delhez	*Communication,* R. Delhez, University of Liege, Liege, Belgium
Dept. of Commerce PB Report	*Publication Board Report*, Office of Technical Services, U.S. Department of Commerce, Washington, D.C.
Diox Process	*The Diox Process,* Wallace and Tiernan Co., Newark (1949)
Douda	*Air Reactive Compounds: Listing and Properties,* B. E. Douda. RDTR No. 71, AD 632686, U. S. Naval Ammunition Depot, Crane, Ind. (Feb. 24, 1966)
Douglas and Thompson	*Some Studies in Chemical Fire Hazards,* Douglas and Thompson, Oklahoma Engineering Experiment Station (1949)
Dowicil	*Dowicil,* Technical Bulletin, Dow Chemical Co., Midland, Mich.
Doyle	*Communication,* W. H. Doyle, Factory Insurance Association, Hartford, Conn.
Dupont Prod. Inf. Bull.	*Product Information Bulletins,* E. I. duPont de Nemours, Inc., Wilmington, Dela.
Durrant	*Introduction to Advanced Inorganic Chemistry,* P. J. Durrant and B. Durrant, John Wiley & Sons, Inc., New York (1962)
Edin. Roy. Soc.	Edinburgh Royal Society, Edinburgh
Ellern (1961)	*Modern Pyrotechnics,* H. Ellern, Chemical Publishing Co., Inc., New York (1961)
Ellern (1968)	*Military and Civilian Pyrotechnics*, H. Ellern, Chemical Publishing Co., Inc., New York (1968)
"Ethyl" Sodium	*Handling "Ethyl" Sodium*, Ethyl Corp., New York (1954)
Ethyleneimine	*Ethyleneimine,* Dow Chemical Co., Midland, Mich.

Fatt and Tashima	*Alkali Metal Dispersions,* I. Fatt and M. Tashima, Van Nostrand, New York
Fawcett	*Communication,* H. H. Fawcett, National Academy of Sciences, Washington, D. C.
Fawcett and Wood	*Safety and Accident Prevention in Chemical Operations,* H. H. Fawcett and W. S. Wood, John Wiley & Sons, Inc., New York (1965).
Federoff	*Encyclopedia of Explosives and Related Items,* B. T. Federoff, et al., Picatinny Arsenal, Dover, New Jersey (1960).
Fire and Accident Prev.	*Fire and Accident Prevention,* Information Bulletin Series, U.S. Atomic Energy Commission, Washington, D. C.
Fire Haz. Prop.	*Fire Hazard Properties of Flammable Liquids, Gases and Volatile Solids,* NFPA No. 325M (1969 Edition), National Fire Protection Assn., Boston
Fire J.	*Fire Journal,* National Fire Protection Association, Boston
Fire Tech.	*Fire Technology,* National Fire Protection Association, Boston
Flynn and Rossow	*Classification of Chemical Reactivity Hazards for the Advisory Committee to the U.S. Coast Guard, National Academy of Sciences.* J.
	P. Flynn and H. E. Rossow, The Dow Chemical Company, Midland, Michigan (1970)
	NOTE: The authors observed temperature and pressure effects when equimolar quantities of two chemicals were mixed in a closed container. In some cases the changes were solely vapor pressure effects due to heat of solution.
Gallais	*Chimie MinŽrale ThŽorique et ExpŽrimentale (Chimie Electronique),* F. Gallais, Masson, Paris (1957)
Gaylord	*Reduction with Complex Metal Hydrides,* N. G. Gaylord, Interscience Publishers, Inc., New York (1956)
Gazz. Chim. Ital.	*Gazzetta Chimica Italiana,* Rome, Italy
Gen. Inorg. Chem.	*General Inorganic Chemistry,* P. J. Durrant, Longmans, Green & Co., Ltd., London, (1953)
German Pat.	*German Patent*

Gilbert's Ann.	*Gilbert's Annalen der Physik*
Gracie and Droher	*A Study of Sodium Fires*, J. D. Gracie and J. J. Droher, Atomics International NAA SR 4383, Conoga Park, California (1960)
Greaves	*Communication*, G. A. Greaves, Explosives Branch, Mines Department, Perth, Western Australia
Grignard	*Traite de Chimie Organique,* Grignard, Dupont and Locquin, Masson, Paris (1935-1954)
Halane — Prelim. Info. Sheet	*Halane — Preliminary Information Sheet*, Wyandotte Chemicals, Wyandotte, Mich. (1953)
Hampel	*Rare Metals Handbook*, 2nd ed., C. A. Hampel, editor, Reinhold, New York (1961)
Handbook Chem. Phys.	*Handbook of Chemistry and Physics*, Chemical Rubber Publishing Co., Cleveland
Haz. Chem. Data	*Hazardous Chemicals Data*, NFPA No. 49 (1966 Edition), National Fire Protection Assn., Boston
Hazards Home Chem.	"Hazards of Home Chemistry," H. H. Fawcett, *Transactions*, National Safety Congress, National Safety Council, Chicago (1963)
Health & Safety Inf.	*Health and Safety Information,* U.S. Atomic Energy Commission, Washington, D.C.
Helv. Chim. Acta	*Edenda Curat Societas Chimica Helvetica*, Verlag Helvetica Chimica Acta, Basel, Switzerland
Helv. Chim. Acta	*Helvetica Chimica Acta,* Basel, Switzerland
Hexagon Alpha Chi Sigma	*The Hexagon of Alpha Chi Sigma,* Indianapolis
Himiceskaja Promyslennost	*Himiceskaja Promyslennost.* Ministry of Chemical Industry, Moscow (U.S.S.R.)
Houghton	*Communication*, J. A. Houghton, Liberty Mutual Fire Insurance Company, Boston
Hurd	*An Introduction to the Chemistry of the Hydrides,* D. T. Hurd, John Wiley and Sons, Inc., New York, (1952)
IIT Progs. Rept.	*Inhibition of Flashing of Aerosols,* R. Kamo, Quarterly Progress Report 7, AD 272972, Illinois Institute of Technology (Feb. 21, 1962)

Ind. Eng. Chem.	*Industrial and Engineering Chemistry,* American Chemical Society, Washington, D.C.
Ind. & Eng. Chem. News	*Industrial and Engineering Chemistry,* News Edition, American Chem. Society, Washington, D.C.
Ind. Eng. Chem. Proc. Dev.	*Industrial and Engineering Chemistry, Process Development,* American Chemical Society, Washington, D.C.
Ind. Eng. Chem. Prod. Res.	*Industrial and Engineering Chemistry, Product*
Dev.	*Research and Development,* American Chemical Society, Washington, D.C.
Ind. Saf. Equip.	*Industrial Safety Equipment*
Inf. Exchange Bull.	*Information Exchange Bulletin,* Lawrence Radiation Laboratory, University of California, Livermore
Inorg. Chem.	*Inorganic Chemistry,* American Chemical Society, Washington, D.C.
J. Agri. Food Chem.	*Journal of Agriculture and Food Chemistry,* American Chemical Society, Washington, D.C.
J. Am. Chem. Soc.	*Journal of the American Chemical Society,* Washington
J. Am. Rocket Soc.	*Journal of the American Rocket Society,* New York
J. Chem. Edu.	*Journal of Chemical Education,* American Chemical Society, Division of Chemical Education, N.Y.
J. Chem. Eng. Data	*Journal of Chemical and Engineering Data,* American Chemical Society, Washington, D.C.
J. Chem. Phys.	*Journal of Chemical Physics,* American Institute of Physics, New York
J. Chem. Soc.	*Journal of the Chemical Society,* London
J. Chem. Soc. Japan	*Journal of the Chemical Society of*
Ind. Chem. Sect.	*Japan, Industrial Chemistry Section,* Chemical Society of Japan, Tokyo
J. Chim. Phys.	*Journal de Chimie Physique et de Physicochimie Biologique,* SociŽtŽ de Chimie Physique, Paris
J. Indian Chem. Soc.	*Journal of the Indian Chemical Society,* Calcutta

J. Inst. Pet.	*Journal of the Institute of Petroleum,* London
J. Org. Chem.	*The Journal of Organic Chemistry,* American Chemical Society, Washington, D.C.
J. Phys. Chem.	*The Journal of Physical Chemistry,* American Chemical Society, Washington, D.C.
J. Prakt. Chem.	*Journal fŸr Praktische Chemie,* Barth, Leipzig
J. Res. Nat. Bur. Stand.	*Journal of Research, Section A: Physics and*
Sect. A.	*Chemistry* (National Bureau of Standards), Sup't of Documents, Gov't Printing Office, Washington, D.C.
J. Sci. Instr.	*Journal of Scientific Instruments,* Inst. of Physics and the Physical Society, London
J. Soc. Chem. Ind.	*Journal of the Society of Chemical Industry,* Burlington House, London
Jolicoeur	*Communication,* D. J. Jolicoeur, North American Aviation, Inc., El Segundo, California
Karasch	*Organic Sulfur Compounds,* N. Karasch, Pergamon Press, New York (1961)
Kastner's Arch.	*Kastner's Archives*
Katz and Rabinowitch	*Chemistry of Uranium,* J. J. Katz and E. Rabinowitch, McGraw-Hill Co., New York (1951)
Kaufman	*Handbook of Organometallic Compounds,* H. C. Kaufman, D. Van Nostrand Co., Inc., New York (1961)
Kharasch	*Organic Sulfuric Compounds,* W. Kharasch, Editor, Pergamon Press, Elmsford, N.Y. (1961)
Khim. Prom. USSR	*Khimicheskaya Promyshlennost USSR,* Leningrad
Kirk and Othmer	*Encyclopedia of Chemical Technology,* Kirk and Othmer, Interscience Publishers, New York (1947)
Kirk and Othmer, Second Ed.	*Encyclopedia of Chemical Technology, Second Edition,* Kirk and Othmer, Interscience Publishers, New York (1963).
Kirschenbaum	*Fundamental Studies of New Reactions,* Final Report, A. O. Kirschenbaum, Office of Ordnance Research Institute, Temple University, Philadelphia (1956).

Kit and Evered — *Rocket Propellant Handbook,* B. Kit and D. S. Evered, The Macmillan Co., New York (1960).

Kite — *Communication,* G. F. Kite, Phillip Morris Research Center, Richmond, Va.

Kittila — *Dimethylformamide Chemical Uses,* R. S. Kittila, E. I. duPont de Nemours, Wilmington, Del. (1967).

Klotz — *Communication,* M. O. Klotz, Ottawa Civic Hospital, Ottawa, Ontario.

Kruk-Schuster — *A. Kruk-Schuster*, Laboratory Chemical

Lab. Govt. Chemist — *Laboratory of the Government Chemist,* "Rules for the Packing, Storage, and Labelling of Explosives for Carriage by Sea," Board of Trade, London (1965)

Laccabue — *Report No. 7E 1500, Fluorolube-Aluminum Detonation Point,* J. R. Laccabue, Convair (Astronautic Division), General Dynamics Corp., San Diego (1958)

Latimer and Hildebrand — *Reference Book of Inorganic Chemistry*, Latimer & Hildebrand, Macmillan Co., New York (1940)

Lawless and Smith — *High Energy Oxidizers,* E. W. Lawless and I. C. Smith, Marcel Dekker, Inc., New York (1968)

Lehman and Wilson — *The Inflammable Properties of Combustible Materials, Part I,* A. S. Lehman and W. B. Wilson. Final Rept. AD 455079, Shell Development Co., Emeryville, Calif. (June 30, 1949)

Lockheed — *Aluminum Hydride, A Literature Review,* Lockheed Aircraft Corp., Tech. note, AD 244583, p. 3. Sunnyvale, Calif. (Aug. 1960)

Lowig — *Das Brom und seine chemische Vorhaltnisse,* C. Lowig, Heidelberg (1829)

Magnesium Standard — *Standard for the Storage, Handling and Processing of Magnesium,* No. 48, National Fire Protection Association, Boston

Matheson Gas Data — *Matheson Gas Data Book,* Matheson Chemical Company, Inc., New York (1961)

Mathieson Chlorine — *Mathieson Chlorine,* Mathieson Chemical Co., New York (1948)

Matsuguma	*Communication,* H. J. Matsuguma, Picatinny Arsenal, Dover, N. J.
MCA Case History	*Case Histories of Accidents in the Chemical Industry,* Manufacturing Chemists' Assn., Inc., Washington, D. C.
MCA Guide for Safety	*Guide for Safety in the Chemical Laboratory* (Second Edition), Van Nostrand Publishing Company, New York (1972)
MCA Task Group, POCl	*Safety and Fire Protection Committee, Task Group on Hazards of POCl,* Manufacturing Chemists' Association, Washington, D. C.
Mellor	*A Comprehensive Treatise on Inorganic and Theoretical Chemistry,* J. W. Mellor, Longmans, Green & Co., London (1946-1947)
Mem. Poudres	*MŽmorial des Poudres,* Paris
Mem. Proc. Manchester Lit. Phil. Soc.	*Memoirs and Proceedings of the Manchester Literary Philosophical Society,* Manchester, England
Merck Index	*The Merck Index of Chemicals and Drugs,* Merck & Co., Inc., Rahway, N. J.
Merck Safety Report	Merck & Co., Inc., Rahway, N. J.
Metallic Sodium	*Handling Metallic Sodium,* National Distillers Chemical Corp., New York (1951)
Mich. Occ. Health	*Michigan's Occupational Health,* Div. of Occupational Health, Mich. Dept. of Health, Lansing, Mich.
Military Explosives	*Military Explosives,* TM 9-2900, War Department, U.S. Government.
Miller	*Acetylene, Its Properties, Manufacture and Uses,* Vol. 1, S. A. Miller, Academic Press, Inc., New York (1965)
Moissan	*Le Fluor et ses ComposŽs,* H. Moissan, Paris (1900)
Monroe	*Communication,* R. F. Monroe, Dow Chemical Company, Midland, Michigan
Morse	*Communication,* A. R. Morse, National Research Council, Ottawa.
Mukerjee	*Communication,* N. C. Mukerjee. Chemplast, P. O. Raman

	Nagar, Tamilnadu, India
Mustaparta	*Communication*, G. R. Mustaparta, Hercules Incorporated, Cumberland, Maryland.
N. A. Aviation	*Comparative Flammability Testing of Insulated Wire,* North American Aviation, Inc., El Segundo, California
NAS-USCG Advis. Com.	*NAS-USCG Advisory Committee on Hazardous Materials,* "A Study of the Hazards Created by Gas Evolution in the Transportation of Liquid Sulfur," Washington, D.C. (1966)
NASA SP-3037	*NASA SP-3037*, H. W. Schmidt and J. T. Harper, "Handling and Use of Fluorine and Fluorine-Oxygen Mixtures in Rocket Systems," National Aeronautics and Space Administration, Washington, D.C. (1967)
Naturwissenschaften	*Naturwissenschaften,* Springer, Berlin
NavAer	*NavAer, Bureau of Aeronautics,* U.S. Navy, Washington, D.C.
NAVWEPS OP 3237	*NAVWEPS OP 3237*, Bureau of Naval Weapons, Department of the Navy, Washington, D.C.
NBFU Research Report	*Research Report,* National Board of Fire Underwriters, New York
NFPA Fire News	*Fire News,* National Fire Protection Assn., Boston
NFPA Quarterly	*Quarterly,* National Fire Protection Assn., Boston
NSC Data Sheet	*Data Sheet,* National Safety Council, Chicago
NSC Nat. Saf. News	*National Safety News,* National Safety Council, Chicago
NSC Newsletter, Aero. Sec.	*Newsletter, Aerospace Section,* National Safety Council, Chicago
NSC Newsletter, Campus Safety	*Newsletter, Campus Safety Association,* National Safety Council, Chicago
NSC Newsletter, Chem. Sec.	*Newsletter, Chemical Section,* National Safety Council, Chicago
NSC Newsletter, R & D Sec.	*Newsletter, Research and Development Section,* National Safety Council, Chicago
Occ. Haz.	*Occupational Hazards,* Industrial Publishing Co.,

	Cleveland, Ohio
Occupancy Fire Record	*Occupancy Fire Record,* National Fire Protection Assn., Boston
Oldbury Chemicals	*Oldbury Chemicals,* Oldbury Electro-Chemical Co., Niagara Falls, N. Y.
Organic Synthesis	*Organic Synthesis,* Collective Volume III, E. C. Horning, ed., John Wiley & Sons, New York (1955)
Pancner	*Communication,* F. O. Pancner, Argonne National Laboratory, Argonne, Illinois
Pascal	*Traite de chimie minŽrale,* Paul Pascal, Paris, Masson (1931-1934)
Pease	*Project Squid,* R. N. Pease. Quarterly Rept. TIP U12580, Princeton Univ., N.J. (March 31, 1950)
Phar. Weekblad	*Pharmaceutisch Weekblad,* Centen Pub. Co., Hilversum, Netherlands
Phil. Trans. Roy. Soc. London	*Philosophical Transactions of the Royal Society of London,* London
Phot. Sci. Eng.	*Photographic Science and Engineering,* Society of Photographic Scientists and Engineers, Washington, D.C.
Pieters	*Safety in the Chemical Laboratory,* 2nd. Edition, H.A.J. Pieters and J. W. Creyghton, Academic Press, Inc., New York (1957)
Poole	*Communication,* H. G. Poole, Bureau of Mines, Albany, Ore.
Pouwels	*Communication,* H. Pouwels, ACF Chemiefarma N.V., Maarssen, Netherlands
Proc. Roy. Soc.	*Proceedings of the Royal Society of London*
Reactor Fuel Process.	*Reactor Fuel Processing,* U.S. Government Printing Office, Washington, D.C.
Remy	*Treatise on Inorganic Chemistry,* H. Remy (translated by J. S. Anderson), Elsevier Publishing Co., New York (1956)
RŽpert. Pharm.	*RŽpertoire de Pharmacie,* Paris
Report, Amer. Potash and	*Report of Accident, Dinsmore and DeRopp,*

Chemical Co.	*American Potash and Chemical Co.,* Trona, Calif.
Report Anal. Chem.	*Analytical Chemistry,* Washington
Report, L. A. Fire Dept.	*Report,* Los Angeles Fire Department
Rev. Met.	*Revue de MŽtallurgie*, Paris
Ripley	*A Background Survey of Air and Water Reactive Materials and Their Uses,* W. Ripley. RDTN No. 32, U.S. Naval Ammunition Depot, Crane, Ind. (Oct. 28, 1966)
Roblee	*Communication,* C. L. Roblee, University of Illinois, Champaign-Urbana, Ill.
Rocketdyne Rept., Hypergol	*Hypergol Cartridge Maintenance and Storage,* Rocketdyne (North American Aviation, Inc.), R-3066; AD 445908, Canoga Park, Calif. (July 13, 1961)
Rolston	*Communication,* C. H. Rolston, duPont Research and Development Center, Wilmington, Del.
Rose	*The Condensed Chemical Dictionary,* A. Rose, E. Rose and F. M. Turner, Reinhold Publishing Corp., New York (1961)
RŸst and Ebert	*UnfŠlle Beim Chemischen Arbeiten,* E. RŸst and A. Ebert, Rascher Verlag, ZŸrich (1948)
Rutledge	*Acetylenic Compounds,* T. F. Rutledge, Reinhold, New York (1968)
Safety Eng.	*Safety Engineering,* New York
Safety Eng. Reports	*Safety Engineering Reports,* California Division of Industrial Safety, Sacramento
Scaros and Serauskas	*Communication,* M. G. Scaros and J. A. Serauskas, Searle Laboratories, Chicago
Schwab	*Communication,* R. F. Schwab, Allied Chemical Corporation, Morristown, N.J.
Schweigger's Jour.	*Schweigger's Journal*
Science	*Science,* American Assn. for The Advancement of Science, Washington, D.C.
Scott	*Communication,* R. H. Scott, Batelle-Northwest, Richland, Washington
Serious Acc. Series	*Serious Accident Series,* U.S. Atomic Energy Commission,

	Washington, D.C.
Short	*Communication,* J. F. Short, The Distillers Company, Ltd., Great Burgh, Epsom, Surrey, England
Sidgwick	*The Chemical Elements and Their Compounds,* N. V. Sidgwick, Oxford University Press, New York (1950)
Smart	*The Technology of Industrial Fire & Explosion Hazards,* R. C. Smart, Chapman & Hall, London (1947)
Sodium, Plant Scale	*Handling Metallic Sodium on a Plant Scale,* U.S. Industrial Chemicals, Inc., New York (1956)
Spence	*Communication,* S. F. Spence, American Cyanamid Co., Wayne, N.J.
Sprengstoffe, Waffen u.	*Sprengstoffe, Waffen und Munitions,*
Munitions	Charlotteburg, Germany (1905)
Staub	*Staub* (Dust) VDI-Verlag GmbH Duesseldorf, Germany
Stecher	*Fire Prevention and Protection Fundamentals,* G. E. Stecher and H. N. Lendall, Chilton Co., Philadelphia (1953)
Stephenson	*Communication,* F. G. Stephenson, Manufacturing Chemists' Association, Washington, D.C.
1965 Sum. Serious Acc.	*1965 Summary of Serious Accidents,* U.S. Atomic Energy Commission, Washington, D.C. (1966)
Svenska Akad.	*Svenska Akademien,* Stockholm, Handlingar, Series 2
Swanson	*Communication,* J. L. Swanson, Battelle-Northwest, Richland, Washington
Symposium Comb. (Fourth)	*Symposium on Combustion (Fourth),* Williams & Wilkins, Baltimore, Md. (1953)
Symposium Comb. (Fifth)	*Symposium on Combustion (Fifth),* Reinhold, New York (1955)
Taylor	*Taylor's Scientific Memoirs,* A. J. Taylor (1831)
Tenn. Eastman	*Safety Memorandum,* Tennessee Eastman, Co., Kingsport, Tenn.
Title 46	Code of Federal Regulations: Title 46 — Shipping [Parts 146 to 149], Washington, D.C.

Trans. Faraday Soc.	*Transactions of the Faraday Society,* Aberdeen
Trans. Roy. Soc., Can. Sect. III	*Transactions of the Royal Society of Canada*, Section III, Ottawa
Tricon	*Communication,* A. J. Tricon, Houston, Texas
Tr. po Khim. i Khim. Tekhnol.	*Trudy po Khimii i Khimicheskoi Tekhnologii, Gorki, U.S.S.R.*
Turley	*Safety Study of Halogenated Hydrocarbon-Nitrogen Tetroxide Detonations,* M64-171, R. E. Turley, Martin Co., Denver (1964)
UL Bull. Research	*Bulletin of Research,* Underwriters' Laboratories, Inc., Chicago
Urbanski	*Chemistry and Technology of Explosions,* T. Urbanski, Pergamon Press, New York (1964)
USAEC Document	*Research and Development Report,* U.S. Atomic Energy Commission, Washington, D.C.
U.S. Army Ord. Safety Man.	*U.S. Army Ordnance Safety Manual,* Rev. 4, Washington (1951)
USDA Tech. Bull.	*U.S. Department of Agriculture Technical Bulletin,* Washington, D.C.
U.S. Pat.	*U.S. Patent*
U.S. Pat. Gaz.	*Official Gazette,* U.S. Patent Office, Washington, D.C.
U. Wash. Occ. Health	*University of Washington Occupational Health*
Newsletter	*Newsletter*, Environmental Health Division, Seattle, Wash.
Van Dolah	*Communication,* R. W. Van Dolah, Bureau of Mines, Pittsburgh, Pa.
Van Slyke	*Communication,* W. J. Van Slyke, Battelle-Northwest, Richland, Wash.
Van Wazer	*Phosphorus and Its Compounds. Vol. 1,* J. R. Van Wazer, Interscience Publishers Inc., New York (1958)
Veiligheid	*Veiligheid, de Amsterdam,* Veiligheidsinstituut, Amsterdam
Ventrone	*Communication*, T. A. Ventrone, American Cyanamid Co., Bound Brook, N. J.
Vervalin	*Fire Protection Manual for Hydrocarbon Processing*

Plants, C. H. Vervalin, Gulf Publishing Co., Houston (1964)

Von Schwartz — *Fire and Explosion Risks,* E. Von Schwartz, Griffin & Co., London (1918)

Von Schwartz and Salter — *Fire and Explosions Risks*, E. Von Schwartz; Translated from the revised German edition by Charles T. C. Salter, Griffen & Co., London (1940)

Wallace — *Communication*, E. R. Wallace, Eastman Kodak Co., Rochester, N. Y.

Waller and Mandell — *Communication,* D. K. Waller and D. Mandell, Los Angeles

WAPD-TM — *Westinghouse Atomic Power Division Technical Memorandum,* Clearinghouse for Federal Scientific and Technical Information, U. S. Department of Commerce, Springfield, Virginia

Weed — *Communication*, R. D. Weed, Battelle-Northwest, Richland, Washington

Wheeler — *Communication*, J. J. Wheeler, Eastman Kodak Co., Rochester, New York

Whitmore — *Organic Chemistry*, F. C. Whitmore, D. Van Nostrand, New York (1937)

Wick — *Plutonium Handbook,* Vol. 1, O. J. Wick et al, Gordon and Breach, Science Publishers, Inc., New York (1967)

Wischmeyer — *Communication,* F. W. Wischmeyer, Eastman Kodak Co., Rochester, N. Y.

Wood — *Communication,* W. S. Wood, Sun Oil Company, Philadelphia (1966).

Woodcock — *Communication,* S. J. Woodcock, Battelle-Northwest, Richland, Wash.

Yunker — *Communication,* W. Yunker, Battelle-Northwest, Richland, Wash.

Z. Angew. Chem. — *Zeitschrift fŸr angewandte Chemie,* Verlag Chemie, Weinheim, Germany

Z. Anorg. Chemie — *Zeitschrift fŸr anorganische und allgemeine Chemie,* Barth, Leipzig

Zeiss	*Organometallic Chemistry*, H. Zeiss, Reinhold Publishing Corp., New York (1960)
Z. Elektrochem	*Zeitschrift fŸr Elektrochemie und angewandte physikalische Chemie,* Verlag Chemie, Weinheim, Germany
Zh. Obshch. Khim.	*Zhurnol Obshchei Khimii,* U.S.S.R.
Z. Naturforsch	*Zeitschrift fuer Naturforschung*, Tuebinger, West Germany

NFPA 495

1996 Edition

Explosive Materials Code

1996 Edition

This edition of NFPA 495, *Explosive Materials Code,* was prepared by the Technical Committee on Explosives and acted on by the National Fire Protection Association, Inc. at its Annual Meeting held May 20-23, 1996, in Boston, MA. It was issued by the Standards Council on July 18, 1996, with an effective date of August 9, 1996, and supersedes all previous editions.

Changes other than editorial are indicated by a vertical rule in the margin of the pages on which they appear. These lines are included as an aid to the user in identifying changes from the previous edition.

This document has been submitted to ANSI for approval.

Origin and Development of NFPA 495

This code was originally issued in 1912 under the title *Suggested State Law to Regulate the*

Manufacture, Storage, Sale, and Use of Explosives. The second edition was issued in 1941 by the Committee on Laws and Ordinances and retitled *Suggested Explosives Ordinance for Cities*. Later, the document was designated as NFPA 495L.

After being assigned to the Committee on Chemicals and Explosives, a new edition was issued in 1959. This was retitled as the *Code for the Manufacture, Transportation, Storage, and Use of Explosives and Blasting Agents* and redesignated as NFPA 495.

Following the reorganization of the committee in 1960, the responsibility for amendments to NFPA 495 was assigned to the Sectional Committee on Explosives. This committee reported to the Correlating Committee of the Committee on Chemicals and Explosives. Revised editions were issued in 1962, 1965, 1967, 1968, 1969, and 1970. A new edition was issued in 1972, with the document title revised to *Code for the Manufacture, Transportation, Storage, and Use of Explosive Materials*. A subsequent edition followed in 1973.

Following the issuance of the 1973 edition, the Sectional Committee on Explosives was redesignated as a Technical Committee. In 1976, the committee began a detailed review intended to amend requirements to eliminate conflicts with the regulations promulgated by the various federal agencies concerned with explosive materials (e.g., U.S. Bureau of Alcohol, Tobacco, and Firearms, U.S. Mine Safety and Health Administration, and U.S. Department of Transportation). This effort resulted in the 1982 edition, which was subsequently followed by a new edition in 1985. In 1990, the document was again revised and the title changed to *Explosive Materials Code*. The 1992 edition incorporated various technical and editorial amendments.

The latest edition, issued in 1996, incorporates changes in the classification of explosives to conform with recent U.S. Department of Transportation "Hazardous Materials Regulations," which in turn are based on United Nations Recommendations on the Transport of Dangerous Goods. The 1996 edition also includes technical and editorial amendments.

Technical Committee on Explosives

J. Edmund Hay, *Chair*
U.S. Bureau of Mines, PA

W. S. Chang, Bureau of Explosives Lab, NJ

John A. Conkling, Chestertown, MD

C. James Dahn, Safety Consulting Engr Inc., IL

Paul W. Dickinson, Defense Logistics Agency, CO

Thomas P. Dowling, Inst. of Makers of Explosives, DC
Rep. Inst. of Makers of Explosives

Frank H. Fenton, III, The Township of Northampton, PA

Richard L. Fischer, Mine Safety & Health Admin., CO

Mark A. Fry, Mark A. Fry & Assoc., Inc., NJ

Charles C. Gardner, Hercules Inc., VA

Kenneth L. Kosanke, Pyrolabs, CO

William J. Maurits, U.S. DOD Explosives Safety Board, VA

Larry J. McCune, U.S. Bureau of Alcohol, Tobacco & Firearms, DC

John G. Robert, Industrial Risk Insurers, CT
Rep. Industrial Risk Insurers

Robert A. VanDuzer, SAAMI, PA
Rep. Sporting Arms & Ammunition Mfrs. Inst., Inc.

Alternates

Michael S. Katich, Defense Logistics Agency, CO
(Alt. to P. W. Dickinson)

Roger N. Prescott, Austin Powder Co., OH
(Alt. to T. P. Dowling)

Lon D. Santis, U.S. Bureau of Mines, PA
(Alt. to J. E. Hay)

David S. Shatzer, U.S. Bureau of Alcohol, Tobacco & Firearms, DC
(Alt. to L. J. McCune)

Nonvoting

Glen E. Gardner, U.S. Occupational Safety & Health Admin., DC

Charles Schultz, U.S. Dept. of Transportation, DC

Terence P. Smith, U.S. Dept. of Labor, DC
(Alt. to G. E. Gardner)

David G. Trebisacci, NFPA Staff Liaison

This list represents the membership at the time the Committee was balloted on the text of this edition. Since that time, changes in the membership may have occurred.

NOTE: Membership on a Committee shall not in and of itself constitute an endorsement of the Association or any document developed by the Committee on which the member serves.

Committee Scope: This Committee shall have primary responsibility for documents safeguarding against the fire and life hazards associated with explosives and related materials during their manufacture, storage, transportation and use. The sale and use of fireworks and model rockets are the responsibility of the Technical Committee on Pyrotechnics.

NFPA 495
Explosive Materials Code

1996 Edition

NOTICE: An asterisk (*) following the number or letter designating a paragraph indicates explanatory material on that paragraph in Appendix A.
Information on referenced publications can be found in Chapter 11 and Appendices D and F.

Chapter 1 General

1-1 Scope.

1-1.1

This code shall apply to the manufacture, transportation, storage, sale, and use of explosive materials.

1-1.2

This code shall not apply to the transportation of explosive materials where under the jurisdiction of the U.S. Department of Transportation (DOT). It shall apply, however, to state and municipal supervision of compliance with "Hazardous Materials Regulations," U.S. Department of Transportation, Title 49, *Code of Federal Regulations*, Parts 100-199.

1-1.3

This code shall not apply to the transportation and use of military explosives by federal or state military agencies, nor shall it apply to the transportation and use of explosive materials by federal, state, or municipal agencies while engaged in normal or emergency performance of duties.

1-1.4

This code shall not apply to the manufacture of explosive materials under the jurisdiction of the U.S. Department of Defense. This code also shall not apply to the distribution of explosive materials to or storage of explosive materials by military agencies of the United States, nor shall it apply to arsenals, navy yards, depots, or other establishments owned by or operated by or on behalf of the United States.

1-1.5

This code shall not apply to pyrotechnics such as flares, fuses, and railway torpedoes. It also shall not apply to fireworks and pyrotechnic special effects as defined in NFPA 1123, *Code for Fireworks Display*; NFPA 1124, *Code for the Manufacture*, *Transportation*, *and Storage of Fireworks*; and NFPA 1126, *Standard for the Use of Pyrotechnics before a Proximate Audience*.

1-1.6

This code shall not apply to model and high power rocketry as defined in NFPA 1122, *Code for Model Rocketry*; NFPA 1125, *Code for the Manufacture of Model Rocket and High Power Rocket Motors*; and NFPA 1127, *Code for High Power Rocketry*.

1-1.7

This code shall not apply to the use of explosive materials in medicines and medicinal agents in the forms prescribed by the United States Pharmacopeia or the National Formulary.

1-2 Purpose.

This code is intended to provide reasonable safety in the manufacture, storage, transportation, and use of explosive materials.

1-3 Equivalency.

The authority having jurisdiction shall be permitted to authorize alternate provisions to those in this code to meet unusual conditions, provided such alternate provisions are of substantially equivalent degrees of safety and security.

1-4 Definitions.

The following definitions shall apply for the purposes of this code.

Acceptor. A charge of explosives or blasting agent receiving an impulse from an exploding donor charge.

Ammonium Nitrate. A chemical compound represented by the formula NH_4NO_3.

ANFO (Ammonium Nitrate Fuel Oil Mixture). A blasting agent (Explosive 1.5D) that contains no essential ingredients other than prilled ammonium nitrate and fuel oil.

Approved. Acceptable to the authority having jurisdiction.

NOTE: The National Fire Protection Association does not approve, inspect, or certify any installations, procedures, equipment, or materials; nor does it approve or evaluate testing laboratories. In determining the acceptability of installations, procedures, equipment, or materials, the authority having jurisdiction may base acceptance on compliance with NFPA or other appropriate standards. In the absence of such standards, said authority may require evidence of proper installation, procedure, or use. The authority having jurisdiction may also refer to the listings or labeling practices of an organization concerned with product evaluations that is in a position to determine compliance with appropriate standards for the current production of listed items.

Authority Having Jurisdiction. The organization, office, or individual responsible for approving equipment, an installation, or a procedure.

NOTE: The phrase "authority having jurisdiction" is used in NFPA documents in a broad manner, since jurisdictions and approval agencies vary, as do their responsibilities. Where public safety is primary, the authority having jurisdiction may be a federal, state, local, or other regional department or individual such as a fire chief; fire marshal; chief of a fire prevention bureau, labor department, or health department; building official; electrical inspector; or others having statutory authority. For insurance purposes, an insurance inspection department, rating bureau, or other insurance company representative may be the authority having jurisdiction. In many circumstances, the property owner or his or her designated agent assumes the role of the authority having jurisdiction; at government installations, the commanding officer or departmental official may be the authority having jurisdiction.

Binary Explosive. A blasting explosive formed by mixing or combining two plosophoric materials (e.g., ammonium nitrate and nitromethane).

Blast Area. The area including the blast site and the immediate adjacent area within the influence of flying rock, missiles, and concussion.

Blaster. A person qualified to be in charge of and responsible for the loading and firing of a blast.

Blasting Agent.* A material or mixture intended for blasting that meets the requirements of the DOT "Hazardous Materials Regulations," as set forth in Title 49, *Code of Federal Regulations*, Parts 173.56, 173.57, and 173.58, Explosive 1.5D.

Blast Site.* The area where explosive material is handled during loading of the blasthole, including 50 ft (15.2 m) in all directions from the perimeter formed by loaded holes. A minimum of 30 ft (9.1 m) can replace the 50-ft (15.2-m) requirement if the perimeter for loaded holes is marked and separated from nonblast site areas by a barrier. The 50-ft (15.2-m) or 30-ft (9.1-m) distance requirements, as applicable, apply in all directions along the full depth of the blasthole. In underground mines, at least 15 ft (4.6 m) of a solid rib, pillar, or broken rock can be substituted for the 50-ft (15.2-m) distance.

Bulk Mix. A mass of explosive material prepared for use in bulk form without packaging.

Bulk Mix Delivery Equipment. Equipment (usually a motor vehicle with or without a mechanical delivery device) that transports explosive materials in bulk form for mixing or loading directly into boreholes, or both.

Bullet-Resistant Construction.* Refers to magazine walls or doors, constructed to resist penetration of a bullet of 150-grain M2 ball ammunition having a nominal muzzle velocity of 2700 fps (824 mps) when fired from a 0.30-caliber rifle from a distance of 100 ft (30.5 m) perpendicular to the wall or door.

Bullet-Sensitive Explosive Material. Explosive material that can be detonated by 150-grain M2 ball ammunition having a nominal muzzle velocity of 2700 fps (824 mps) when fired from a 0.30-caliber rifle at a distance of 100 ft (30.5 m), measured perpendicularly. The test material is at a temperature of 70°F to 75°F (21°C to 24°C) and is placed against a $^{1}/_{2}$-in. (12.7-mm) steel plate.

Cap-Sensitive Explosive Material.* Any explosive material that can be detonated by means of a No. 8 blasting cap or its equivalent.

Composite Propellant. A mixture consisting of an elastomeric-type fuel and an oxidizer. Composite propellants are used in gas generators and rocket motors.

Detonating Cord. A flexible cord containing a center core of high explosive used to detonate other explosives.

Detonator. Any device containing an initiating or primary explosive that is used for initiating detonation. A detonator is not permitted to contain more than 10 g of total explosive material per unit, excluding ignition or delay charges. The term includes, but is not limited to, electric detonators of the instantaneous and delay types, detonators for use with safety fuses, detonating cord delay connectors, and nonelectric detonators of the instantaneous and delay types that consist of a detonating cord, a shock tube, or any other replacement for electric leg wires.

Donor. An exploding charge producing an impulse that impinges upon an explosive acceptor charge.

Emulsion Explosive. An explosive material that consists of a slurry of substantial amounts of ammonium nitrate dissolved in water droplets surrounded by an oil-like material.

Explosive.* Any chemical compound, mixture, or device, the primary or common purpose of which is to function by explosion. The term includes, but is not limited to, dynamite, black powder, pellet powder, initiating explosives, detonators, safety fuses, squibs, detonating cord, igniter cord, and igniters.

The term includes any material determined to be within the scope of Title 18, *United States Code*, Chapter 40, "Importation, Manufacture, Distribution and Storage of Explosive Materials," and also includes any material classified as an explosive by the U.S. Department of Transportation, "Hazardous Materials Regulations," 49 CFR, Parts 100-199.

Explosive-Actuated Device. Any tool or special mechanized device that is actuated by explosive materials. The term does not include propellant-actuated devices (*see definition of Propellant-Actuated Device)*. Examples of explosive-actuated devices are jet-tappers and jet perforators.

Explosive Material. Any explosive, blasting agent, emulsion explosive, water gel, or detonator.

Fire Extinguisher Rating. A rating set forth in NFPA 10, *Standard for Portable Fire Extinguishers*. This rating is identified on an extinguisher by a number (e.g., 5, 20, 70), indicating relative effectiveness, followed by a letter (e.g., A, B, C, or D) indicating the class or classes of fires for which the extinguisher has been found to be effective.

Fire-Resistant. Construction designed to provide reasonable protection against fire. For exterior walls of magazines constructed of wood, this is defined as the fire resistance equivalency provided by sheet metal of not less than 26 gauge.

Flash Point.* The lowest temperature at which vapors from a volatile combustible substance ignite in air when exposed to flame.

Fuel. Any substance that reacts with the oxygen in the air or with the oxygen yielded by an oxidizer to produce combustion.

Hardwood. Any close-grained wood such as oak, maple, ash, or hickory that is free from loose knots, wind shakes, or similar defects.

High Explosive Materials. Explosive materials that are characterized by a very high rate of reaction, high pressure development, and the presence of a detonation wave.

Highway. Any public street, public alley, or public road.

Inhabited Building. Any building or structure regularly used in whole or part as a place of human habitation. The term includes any church, school, store, railway passenger station, airport passenger terminal, and any other building or structure where people are accustomed to congregate or assemble. The term does not include any building or structure occupied in connection with the manufacture, transportation, storage, or use of explosive materials.

Labeled. Equipment or materials to which has been attached a label, symbol, or other identifying mark of an organization that is acceptable to the authority having jurisdiction and concerned with product evaluation that maintains periodic inspection of production of labeled equipment or materials and by whose labeling the manufacturer indicates compliance with appropriate standards or performance in a specified manner.

Listed. Equipment, materials, or services included in a list published by an organization acceptable to the authority having jurisdiction and concerned with evaluation of products or services that maintains periodic inspection of production of listed equipment or materials or periodic evaluation of services and whose listing states either that the equipment, material, or service meets identified standards or has been tested and found suitable for a specified purpose.

NOTE: The means for identifying listed equipment may vary for each organization concerned with product evaluation, some of which do not recognize equipment as listed unless it is also labeled. The authority having jurisdiction should utilize the system employed by the listing organization to identify a listed product.

Low Explosive Material. Explosive material that is characterized by deflagration or a low rate of reaction and the development of low pressure.

Magazine. A building or structure, other than an explosives manufacturing building, approved for the storage of explosive materials.

Manufacturing. Mixing, blending, extruding, assembling, disassembling, chemical synthesis, and other functions involved in making a product or device that is intended to explode.

Mass Detonate (Mass Explode). Simultaneous detonation or explosion of the total amount or a substantial amount of a quantity of explosive material caused by the explosion of a unit or part of the explosive material.

Misfire. A charge of explosive material that fails to detonate completely after initiation.

Motor Vehicle. Any self-propelled vehicle, truck, tractor, semitrailer, or truck-trailer combination used for the transportation of freight over public highways.

Nonelectric Delay Device. A detonator with an integral delay element used in conjunction with and capable of being initiated by a detonating impulse.

Oxidizing Material.* Any solid or liquid that readily yields oxygen or other oxidizing gas or that readily reacts to oxidize combustible material.

Person. Any individual, firm, copartnership, corporation, company, association, or joint stock association, including any trustee, receiver, assignee, or personal representative thereof.

Plosophoric Materials. Two or more unmixed, commercially manufactured prepackaged chemical ingredients (including oxidizers, flammable liquids or solids, or similar ingredients) that are *not* classified as explosives but that, where mixed or combined, form a blasting explosive.

Plywood. Exterior grade plywood.

Primer. A unit, package, or cartridge of explosive material used to initiate other explosives or blasting agents and that contains (1) a detonator, or (2) a detonating cord to which is attached a detonator designed to initiate the cord.

Propellant. An explosive that normally functions by deflagration and is used for propulsion purposes. It is classified by the U.S. Department of Transportation, "Hazardous Materials Regulations" as 1.1 (Class A) or 1.3 (Class B), depending on its susceptibility to detonation.

Propellant-Actuated Device. Any tool or special mechanized device or gas generator system that is actuated by a propellant or that releases or directs work through a propellant charge.

Public Conveyance. Any railroad car, streetcar, ferry, cab, bus, airplane, or other vehicle that carries passengers for hire.

Railway. Any steam, electric, diesel electric, or other railroad or railway that carries passengers for hire on a particular line or branch in the vicinity of an explosives storage or manufacturing facility.

Semiconductive Hose. Any hose with an electrical resistance sufficient to limit the flow of stray electric currents to safe levels, yet not high enough to prevent the relaxation of static electric charges to ground. Any hose having a resistance of no more than 2.0 megohms over its entire length and a resistance of no less than 1000 ohms/ft (3280 ohms/m) meets this definition.

Sensitivity. A characteristic of an explosive material, classifying its ability to detonate upon receiving an external impulse such as impact shock, flame, or other influence that can cause explosive decomposition.

Shock Tube. A small diameter plastic tube used for initiating detonators. It contains only a limited quantity of reactive material so that the energy that is transmitted through the tube by means of a detonation wave is guided through and confined within the walls of the tube.

Small Arms Ammunition. Any shotgun, rifle, or pistol cartridge and any cartridge for propellant-actuated devices. This definition does not include military ammunition containing bursting charges or incendiary, tracer, spotting, or pyrotechnic projectiles.

Small Arms Ammunition Primers. Small percussion-sensitive explosive charges encased in a cap and used to ignite propellant powder.

Smokeless Propellants. Solid propellants, commonly referred to as smokeless powders, used in small arms ammunition, cannons, rockets, or propellant-actuated devices.

Softwood. Any coarse-grained wood such as fir, hemlock, spruce, or pine that is free from loose knots, wind shakes, or similar defects.

Special Industrial Explosives Device. Explosive-actuated devices and propellant-actuated devices.

Special Industrial Explosive Material.* Shaped materials, sheet forms, and various other extrusions, pellets, and packages of high explosives used for high-energy-rate forming, expanding, and shaping in metal fabrication and for dismemberment and reduction of scrap metal.

Steel. General purpose, hot- or cold-rolled, low carbon steel, such as ASTM A 366, S*pecifications for Commercial Quality Cold-Rolled Carbon Steel Sheets*, or equivalent.

Theft-Resistant. Construction designed to deter illegal entry into facilities for the storage of explosive material.

Two-Component Explosive. See Binary Explosive.

Water Gel.* Any explosive or blasting agent that contains a substantial portion of water.

Weather-Resistant. Construction designed to offer reasonable protection against weather.

Chapter 2 Security and Safety of Explosive Materials

2-1 Basic Requirements.

2-1.1

No attempt shall be made to fight a fire that cannot be contained or controlled before it reaches explosive materials. In such cases, all personnel shall be evacuated immediately to a safe location, and the area shall be guarded from entry by spectators or intruders.

2-1.2

The local fire department and other local emergency response agencies shall be notified of the location of all magazines and shall be notified of any changes in location.

2-1.3

The manufacture of any explosive material, as defined by this code, shall be prohibited unless such manufacture is authorized by federal license and is conducted in accordance with recognized safe practices.

Exception: This requirement shall not apply to hand loading of small arms ammunition prepared for personal use and not for resale.

2-1.4

The manufacture of explosive materials shall be prohibited where such manufacture presents an undue hazard to life or property.

2-1.5

The authority having jurisdiction shall be permitted to restrict the quantity of explosive materials that is handled at any location.

2-1.6

All explosive materials and any newly developed and unclassified explosive materials shall meet the license and permit requirements of this chapter.

Exception: This requirement shall not apply to stocks of small arms ammunition and components thereof, to the extent that they are covered by the provisions of Title 18, United States Code, Chapter 44, "Gun Control Act of 1968."

2-1.7

A person intending to engage in business as an importer of, a manufacturer of, or dealer in explosive materials shall obtain a federal license in accordance with Title 18, *United States Code*, "Organized Crime Control Act of 1970," in Chapter 40.

2-1.8

This chapter is intended to supplement existing federal laws and regulations. Therefore, any person who possesses a license or permit under Title 18, *United States Code,* Chapter 40, that properly covers the activities of such person shall not be required to obtain a permit under this chapter.

2-1.9

All normal access roads to explosive storage magazines shall be posted with the following warning sign:

DANGER

NEVER FIGHT EXPLOSIVE FIRES

EXPLOSIVES ARE STORED ON THIS SITE

CALL ___________________

The sign shall be weather-resistant with a reflective surface and lettering at least 2 in. (50 mm) high.

2-1.10

Placarding shall only apply to Type 5 magazines as defined by Title 27, *Code of Federal Regulations*, Part 55 (Bureau of Alcohol, Tobacco, and Firearms).

2-2 Permit Requirements.

2-2.1

No person shall be in possession of explosive materials, or conduct an operation or activity requiring the use of explosive materials, or perform or supervise the loading and firing of explosive materials without first obtaining the proper permit.

2-2.2

Explosive materials shall not be sold, given, delivered, or transferred to any person not possessing a valid permit.

2-2.3

Every person conducting an operation or activity that uses explosive materials shall obtain a permit to use explosive materials and shall be responsible for the results and consequences of any loading or firing of explosive materials. Such person also shall ensure that loading and firing are performed or supervised by a person possessing a permit to blast.

Exception: Laboratories engaged in testing explosive materials, other than where conducting test blast explosions, shall require only a permit to use.

2-3 Permit Classes.

2-3.1 Permit to Use.

Before a person conducts an operation or activity that uses explosive materials, that person shall obtain a permit to use, which provides authorization to purchase, possess, store, and use such materials.

2-3.2 Permit to Blast.

Before a person supervises and performs the loading and firing of explosive materials, that person shall obtain the appropriate permit to blast, as specified in Table 2-3.2:

Table 2-3.2 Classifications for Permit to Blast

Class	Category	Blasting Permitted
A	Unlimited	All types of blasting
B	General aboveground	All phases of blasting operations in quarries, open pit mines, and aboveground construction
C	General underground	All phases of blasting operations in underground mines, shafts, tunnels, and drifts
D	Demolition	All phases of blasting in demolition projects
E	Seismic	All phases of blasting in seismic prospecting
F	Agriculture	All phases of blasting in agriculture, but limited to not more than 50 lb (22.7 kg) per blast
G	Special	Special blasting as described on the permit

2-4 Requirements for Blaster's Permit.

2-4.1

The applicant for an initial permit to supervise and perform the loading and firing of explosive materials, as specified in 2-3.2, shall demonstrate adequate training and experience in the use of explosive materials in the class authorized by the specific permit for which application is made.

2-4.2

Each applicant shall pass a qualifying examination. The examination may be written, oral, or by such other means as necessary to determine that the applicant is competent to conduct blasting operations and to perform the duties of a blaster.

2-4.3

Any holder of a permit to blast who is convicted of a violation of any explosives law or regulation shall be required to pass a qualifying examination as a condition of retention of the permit.

2-4.4

Any person whose permit to blast has been revoked shall be required to pass a qualifying examination as a condition of reinstatement of the permit.

2-4.5

Any person whose permit to blast has lapsed for a period of 1 year or longer shall be required to pass a qualifying examination as a condition of renewal of the permit.

2-5 Posting of Permits.

2-5.1 Permit to Use.

A copy of the permit shall be posted at each place of operation.

2-5.2 Permit to Blast.

A copy of the permit shall be carried by the permit holder during blasting operations.

2-5.3

Permit holders shall take every reasonable precaution to protect their permits from loss, theft, defacement, destruction, or unauthorized duplication. Any such occurrence shall be reported immediately to the issuing authority.

2-6 Permit Restrictions.

2-6.1

No permit shall be permitted to be assigned or transferred.

2-6.2

No permit shall be issued to a person under 21 years old.

2-6.3

Permits shall be dated and numbered and shall be valid for no longer than 3 years from the date of issue.

2-7 Denial or Revocation of Permits.

2-7.1

A permit for the possession and use of explosive materials shall be denied or revoked for any of the following reasons:

(a) Noncompliance with any order of the issuing authority within the time specified by such order;

(b) Proof that the permit applicant or holder is under indictment for, or has been convicted of, a crime punishable by imprisonment for a term exceeding 1 year;

(c) The applicant or holder is a fugitive from justice;

(d) The applicant or holder is an unlawful user of, or is addicted to, narcotics or dangerous drugs;

(e) The applicant has been adjudicated as mentally defective;

(f) Proof that the permit applicant or holder advocates, or knowingly belongs to, any organization or group that advocates violent overthrow of or violent action against any federal, state, or local government;

(g) Proof that the permit applicant or holder suffers from a mental or physical defect that would interfere with the safe handling of explosives; or

(h) Violation by the permit applicant or holder of any provision of any explosives law or regulation, or proof that false information was provided or a misrepresentation was made to obtain the permit by the applicant or holder.

2-7.2

In any case in which the issuing authority denies or revokes a permit, the issuing authority shall notify the permit applicant or holder promptly. Such notification shall specify the basis for denial or revocation of the permit and shall state that, upon written request by the applicant or holder, a hearing before the issuing authority is to be held within 10 days after the date of the request.

2-7.3

In cases where a hearing is held, the issuing authority shall state its findings and conclusions in writing and shall transmit a copy to the applicant or former permit holder promptly.

2-7.4

Upon notice of the revocation of any permit, the former permit holder shall surrender the revoked permit and all copies thereof to the issuing authority immediately.

2-8 Record Keeping and Reporting.

2-8.1

A holder of a permit to use shall keep a record of all transactions or operations involving explosive materials. Such record shall be retained for 5 years and shall be made available to the issuing authority upon request.

2-8.2

An accumulation of invoices, sales slips, delivery tickets or receipts, or similar records representing individual transactions shall be considered to satisfy the requirements for record keeping, provided they include the signature of the receiver of the explosive materials.

2-8.3

A holder of a permit to blast shall keep a daily record of all explosive materials received and fired or otherwise disposed of by the permit holder. Such records shall be retained for 5 years and shall be made available to the issuing authority upon request.

2-8.4

A holder of a permit shall notify the issuing authority promptly of any change in address.

2-8.5*

The loss, theft, or unlawful removal of explosive materials shall be reported within 24 hours to the Bureau of Alcohol, Tobacco, and Firearms; to the permit-issuing authority; and to the local law enforcement agency.

2-8.6

Accidents involving explosive material that cause a lost-time injury or property damage shall be reported immediately to the authority having jurisdiction.

2-9 Applications and Renewals.

2-9.1

An application for a permit or for renewal of a permit shall be made to the issuing authority on forms provided by the authority and shall contain such information as is required.

2-9.2

Where an application for renewal is filed with the issuing authority before expiration of the current permit, the renewal shall become effective upon expiration of the current permit. No renewal permit shall be issued more than 30 days prior to the expiration date of the current permit.

2-9.3

An application for renewal filed after the expiration date of the current permit shall be considered an application for a new permit.

Chapter 3 Blasting Agents

3-1 Scope.

3-1.1

Unless otherwise specified in this chapter, blasting agents shall be transported, stored, and used in the same manner as other explosive materials.

3-1.2

Water gels, slurries, and emulsion explosives shall not be subject to the requirements of this chapter. (*See Chapter 4*.)

3-2 Fixed Location Mixing.

3-2.1

Buildings or other facilities used for mixing blasting agents shall be located, in relation to inhabited buildings, passenger railroads, and public highways, in accordance with the American Table of Distances. (*See Table 6-4.1*.)

3-2.2

In determining the distance separating inhabited buildings, passenger railroads, or public highways from potential explosions, the sum of all masses that could propagate (i.e., are closer than the distances specified in Table 6-4.2) from either individual or combined donor masses shall be included. However, where ammonium nitrate is included, only 50 percent of its weight shall be used due to its reduced blast effect.

3-2.3

Buildings used for the mixing of blasting agents shall comply with the requirements of this subsection, unless otherwise specifically approved by the authority having jurisdiction.

3-2.3.1 Buildings shall be constructed of noncombustible materials or of sheet metal on wood studs.

3-2.3.2 Floors shall be of concrete or other noncombustible material. They shall be constructed without open floor drains and without piping into which molten materials could flow and become confined in the event of fire.

3-2.3.3 All fuel oil storage facilities shall be separated from the mixing building and located so that the oil drains away from the mixing plant building if the tank ruptures.

3-2.3.4 The mixing building shall be well ventilated.

3-2.3.5 Heating units that do not depend on the combustion of fuel shall be permitted to be used within the mixing building where properly designed and located. All direct sources of heat shall be provided exclusively from units located outside of the mixing building.

3-2.3.6 Internal combustion engines used to generate electrical power shall be located outside of the mixing building or shall be ventilated and isolated properly by a firewall. The engine exhaust system shall be located so that any spark emission cannot endanger any materials in or adjacent to the mixing building.

3-2.4

Equipment used for mixing blasting agents shall comply with the requirements of this subsection.

3-2.4.1 The design of the mixer shall minimize the possibility of frictional heating, compaction, and confinement. All bearings and drive assemblies shall be mounted outside the mixer and protected against the accumulation of dust. All surfaces shall be accessible for cleaning.

3-2.4.2 Mixing and packaging equipment shall be constructed of materials compatible with the blasting agent composition.

3-2.4.3 Means shall be provided to prevent the flow of fuel oil to the mixer in case of fire. In gravity flow systems, an automatic spring-loaded shutoff valve with a fusible link shall be installed.

3-2.5

The requirements of this subsection shall apply where mixing and handling blasting agent compositions.

3-2.5.1 Oxidizers of small particle size, such as crushed ammonium nitrate prills or fines, shall be handled with special care, due to the possibility of their greater sensitivity.

3-2.5.2 No hydrocarbon liquid fuel with a flash point lower than that of No. 2 fuel oil [i.e., 125°F (51.7°C) minimum or legal minimum] shall be used.

Exception: Fuel oils with flash points no lower than 100°F (37.8°C) shall be permitted to be used at ambient air temperatures below 45°F (7.2°C).

3-2.5.3 Reclaimed crankcase oil shall be permitted to be used, provided each new supply of oil is checked for its compliance with 3-2.5.2.

3-2.5.4 Metal powders, such as aluminum, shall be kept dry and shall be stored in containers or bins that are moisture-resistant and weathertight. Solid fuels shall be handled so that dust explosion hazards are minimized.

3-2.5.5 Peroxides or chlorates shall not be used.

3-2.5.6 The requirements of 3-2.5.3, 3-2.5.4, and 3-2.5.5 shall not apply to compositions that have been tested, classified, and approved by the Associate Administrator for Hazardous Materials Safety in accordance with the provisions of Title 49, *Code of Federal Regulations*.

3-2.6

All electrical switches, controls, motors, and lights located in the mixing room shall comply with NFPA 70, *National Electrical Code*®, Article 502.

Exception: This requirement shall not apply to electrical wiring and equipment located outside the mixing building.

3-2.7

The frame of the mixer and all other equipment that are used shall be electrically bonded and grounded.

3-2.8

Safety precautions at mixing plants shall include the following requirements:

(a) Floors shall have no drains or piping into which molten materials could flow and become confined during a fire.

(b) The floors and equipment of the mixing and packaging rooms or areas shall be cleaned thoroughly on a regular basis to prevent accumulations of oxidizers, fuels, and sensitizers.

(c) The entire building shall be cleaned thoroughly on a regular basis to prevent the excessive accumulation of dust.

(d) Smoking, matches, open flames, spark-producing devices, and firearms shall not be permitted inside of or within 50 ft (15.25 m) of any building or facility used for the mixing of blasting agents.

Exception: Firearms shall be permitted to be carried by authorized guards where approved by the authority having jurisdiction.

(e) The area surrounding the mixing plant shall be kept clear of brush, dried grass, leaves, and other materials for a distance of at least 25 ft (7.63 m).

(f) Empty ammonium nitrate bags shall be disposed of daily in a safe manner.

(g) No welding or open flames shall be permitted in or around the mixing or storage area.

Exception: Where the equipment and the area have been completely washed down and all oxidizing material has been removed.

(h) Before welding on or making repairs to hollow shafts, all oxidizing material shall be removed from the outside and inside of the shaft, and the shaft shall be vented with a minimum $^{1}/_{2}$-in. (13-mm) diameter opening.

(i) Other explosive materials shall not be stored inside of or within 50 ft (15.25 m) of any building or facility used for mixing blasting agents.

3-3 Bulk Mixing and Delivery Vehicles.

3-3.1

The provisions of Section 3-3 shall apply to all bulk mixing and delivery vehicles. The requirements of 3-2.5 also shall apply to bulk delivery and mixing vehicles.

3-3.2

The body of a vehicle for mixing and delivering blasting agents in bulk shall comply with the following requirements:

(a) The body shall be constructed of noncombustible materials.

(b) Vehicles used to transport bulk, premixed blasting agents shall have covered bodies.

(c) All moving parts of the mixing system shall be designed so that heat buildup is prevented. Shafts or axles that make contact with the product shall have outboard bearings with a minimum 1-in. (25.4-mm) clearance between the bearings and the outside of the product container. Attention shall be given to adequate clearance on all moving parts.

(d) The bulk delivery vehicle shall be strong enough to carry the load without difficulty and shall be in good mechanical condition.

3-3.3

Operation of bulk delivery vehicles shall comply with the following requirements:

(a) Vehicles transporting blasting agents shall be driven by and shall be in the charge of only those drivers who are at least 21 years old, who are capable, careful, and reliable, and who possess a valid motor vehicle operator's license. Drivers shall be familiar with all traffic regulations, applicable federal and state regulations pertaining to explosive materials, and the requirements of this code.

(b) The vehicle operator shall be trained in the safe operation of the vehicle and shall be knowledgeable of its mixing, conveying, and related equipment. The operator shall be familiar with the commodities being delivered and the general procedures for handling emergencies.

(c) No person shall be permitted to ride upon, drive, load, or unload a vehicle containing blasting agents while smoking or while under the influence of intoxicants, narcotics, or other dangerous drugs.

(d) Vehicles transporting blasting agents shall be in safe operating condition at all times.

(e) No person shall smoke, carry matches or any flame-producing device, or carry any firearms while in or around bulk vehicles effecting the mixing, transfer, or down-the-hole loading of blasting agents at or near the blasting site.

(f) Caution shall be exercised in moving the vehicle within the blasting area to avoid driving the vehicle over or dragging hoses over firing lines, cap wires, or explosive materials. The driver shall obtain the assistance of a second person to guide the driver's movements while moving the vehicle.

(g) Material shall not be mixed while in transit.

3-3.4

Pneumatic loading from bulk delivery vehicles into blast holes primed with electric blasting caps or other static-sensitive systems shall comply with the following requirements:

(a) A positive grounding device shall be used to prevent the accumulation of static electricity.

(b) A semiconductive discharge hose shall be used.

(c) A qualified person shall evaluate all systems to determine that they adequately dissipate static electricity under potential field conditions.

3-3.5

Repairs to bulk delivery vehicles shall comply with the following requirements:

(a) No welding or open flames shall be used on or around any part of the delivery equipment until all oxidizing material has been removed and the equipment has been washed down completely.

(b) Before welding on or making repairs to hollow shafts, all oxidizing material shall be removed from the outside and inside of the shaft, and the shaft shall be vented with a minimum $^1/_2$-in. (13-mm) diameter opening.

3-4 Bulk Storage Bins.

3-4.1

The bin shall be a Type 5 magazine and shall be waterproof.

3-4.2*

The bin, including supports, shall be constructed of compatible materials and shall be adequately supported and braced to withstand the combination of all loads, including impact forces arising from product movement within the bin and accidental contact between vehicles and the support legs of the bin.

3-4.3

The bin discharge gate shall be designed to provide a closure tight enough to prevent leakage of the stored product. Provision also shall be made for locking the discharge gate.

3-4.4

Bin-loading manways or access hatches shall be hinged or otherwise attached to the bin and shall be designed to allow locking.

3-4.5

Any electrically driven conveyors for loading or unloading bins shall comply with the requirements of NFPA 70, *National Electrical Code*. They shall be designed to minimize damage from corrosion.

3-4.6

Bins containing blasting agents shall be located in accordance with Table 6-4.1 with respect to inhabited buildings, passenger railroads, and public highways.

3-4.7

Bins containing blasting agents shall be located in accordance with Tables 6-4.1 and 6-4.2 with respect to the storage of other blasting agents or explosives.

3-4.8

Bins containing ammonium nitrate shall be separated from the storage of blasting agents and explosives in accordance with Table 6-4.2.

3-4.9

Good housekeeping shall be maintained in the vicinity of any bin containing ammonium nitrate or other blasting agent. This shall include keeping weeds and other combustible materials cleared within 25 ft (7.63 m) of the bin. Accumulations of spilled product shall be prevented.

3-5 Storage of Blasting Agents and Supplies.

3-5.1

Blasting agents and oxidizers used for the mixing of blasting agents shall be stored in accordance with the following requirements:

(a) Blasting agents or ammonium nitrate stored with other explosive materials shall be stored in accordance with the requirements of Section 3-5. The total mass of the blasting agents and $^{1}/_{2}$ of the mass of ammonium nitrate shall be included where computing the total quantity of explosive materials for determining separation distance requirements.

(b) Blasting agents stored entirely separate from other explosive materials shall be stored in a Type 5 magazine or a magazine of higher classification (i.e., lower number).

(c) Magazines in which blasting agents are stored shall be constructed so that there are no open floor drains or piping into which molten materials can flow and become confined in the event of fire.

(d) Semitrailer and trailer vans used for highway or on-site transportation of blasting agents shall be permitted to be used for temporary storage of these materials, provided they are located in accordance with Table 6-4.1 with respect to inhabited buildings, passenger railways, and public highways, and in accordance with Table 6-4.2 with respect to each other. Trailers and semitrailers shall be provided with substantial means for locking, and the doors shall be kept locked.

Exception: Where stocks of blasting agents are actually being placed or removed, the doors of trailers and semitrailers shall not be required to be locked.

3-5.2

Piles of ammonium nitrate and warehouses containing ammonium nitrate shall be separated adequately from readily combustible fuels.

3-5.3

Caked oxidizer, either in bags or in bulk, shall not be loosened by blasting.

3-5.4

Every magazine used for the storage of blasting agents shall be under the supervision of a competent person who shall be at least 21 years old.

3-6 Transportation of Packaged Blasting Agents.

3-6.1

Where blasting agents are transported in the same vehicle with other explosive materials, all the requirements of Chapter 5 shall be met.

3-6.2

Vehicles transporting blasting agents shall be driven by and shall be in the charge of only those drivers who are at least 21 years old, who are capable, careful, and reliable, and who possess a valid motor vehicle operator’s license. The driver shall be familiar with state vehicle and traffic laws.

3-6.3

No matches, firearms, acids, or other corrosive liquids shall be carried in the bed or body of any vehicle carrying blasting agents.

3-6.4

No person shall be permitted to ride upon, drive, load, or unload a vehicle containing blasting agents while smoking or while under the influence of intoxicants, narcotics, or other dangerous drugs.

3-6.5

No person shall transport or carry any blasting agents on any public vehicle carrying passengers for hire.

3-6.6

Vehicles transporting blasting agents shall be in safe operating condition at all times.

3-6.7

Where blasting agents are transported over public highways, the packaging, marking, and labeling of containers of blasting agents shall comply with U.S. Department of Transportation regulations.

3-6.8

Vehicles used for transporting blasting agents on public highways shall be placarded in accordance with U.S. Department of Transportation regulations.

3-7 Use of Blasting Agents.

Persons using blasting agents shall comply with all applicable requirements of Chapters 2 and 7.

Chapter 4 Water Gel and Emulsion Explosive Materials

4-1 Scope.

For the purposes of this chapter, the term "water gel" refers to water gel explosive materials or emulsion explosive materials.

4-2 Types and Classifications.

Water gels shall be classified as Division 1.1D or Division 1.5D Explosives in accordance with U.S. Department of Transportation regulations. They shall be manufactured, transported, stored, and used as specified by this code.

Exception: Where otherwise specified in this chapter.

4-3 Fixed Location Mixing.

4-3.1

Buildings or other facilities used for mixing water gels shall be located in accordance with Table 6-4.1 with respect to inhabited buildings, passenger railroads, and public highways.

In determining the distances separating highways, railroads, and inhabited buildings from potential explosions, as specified in Table 6-4.1, the sum of all masses that can propagate (i.e., that lie at distances less than those specified by Table 6-4.2) from either individual or combined donor masses shall be included. However, where ammonium nitrate is required to be included, only $^1/_2$ of its mass shall be used because of its reduced blast effects.

4-3.2

Buildings used for the mixing of water gels shall comply with the following requirements:

(a) Buildings shall be constructed of noncombustible materials or of sheet metal on wood studs.

(b) Floors shall be of concrete or other noncombustible material. They shall be constructed without open floor drains and without piping into which molten materials could flow and become confined in the event of fire.

(c) Where fuel oil is used, fuel oil storage facilities shall be separated from the mixing plant and located so that the oil will drain away from the mixing building in case of tank rupture.

(d) The mixing building shall be well ventilated.

(e) Heating units that do not depend on the combustion of fuel shall be permitted to be used in the mixing building, where properly designed and located. Direct-fired heating units shall be located outside of the mixing building.

(f) Internal combustion engines used to generate electrical power shall be located outside of the mixing building or shall be isolated by a fire partition and shall be ventilated properly. The engine exhaust system shall be located so that any sparks emission cannot endanger any materials in or adjacent to the mixing building.

Exception: Where otherwise specifically approved by the authority having jurisdiction.

4-3.3

The ingredients used in water gels shall comply with the following requirements:

(a) Ingredients classified as explosives shall be stored as required by Chapter 6.

(b) Nitrate-water solutions shall be stored in tank cars, tank trucks, or fixed tanks without quantity-distance limitations. Spills or leaks that could contaminate combustible materials shall be cleaned immediately.

(c) Metal powders, such as aluminum, shall be kept dry and shall be stored in containers or bins that are moisture-resistant or weathertight.

(d) Ingredients shall not be stored with incompatible materials.

(e) Peroxides or chlorates shall not be used.

4-3.4

Mixing equipment shall meet the following requirements:

(a) The design of the processing equipment, including mixing and conveying equipment, shall be compatible with the materials being handled. The equipment shall be designed to minimize frictional heating, compaction, overloading, and confinement.

(b) Equipment and handling procedures shall be designed to prevent the introduction of foreign objects or material.

(c) Mixers, pumps, valves, and related equipment shall be designed to allow regular and periodic flushing, cleaning, dismantling, and inspection.

(d) All electrical equipment and wiring shall comply with NFPA 70, *National Electrical Code*.

(e) Electric motors and generators shall be provided with suitable overload protection devices. All motors, generators, proportioning devices, and all other electrical enclosures shall be bonded. The grounding conductor to all such equipment shall be effectively bonded to the service-entrance ground connection and to all equipment ground connections in order to provide a continuous path to ground.

4-3.5

Mixing facilities shall meet the following requirements:

(a) The mixing, loading, and ingredient transfer areas where residues and spilled materials can accumulate shall be kept safe. A cleaning and collection system shall be provided for dangerous residues.

(b) A visual inspection of the mixing, conveying, and electrical equipment shall be made daily to ensure that all equipment is in good operating condition. A program of systematic maintenance shall be carried out on a regular schedule.

(c) Heating units that do not depend on the combustion of fuel shall be permitted to be used within the confines of the processing building or area, provided they are equipped with temperature and safety controls and provided they are located away from combustible materials and finished product.

4-4 Bulk Mixing and Delivery Vehicles.

4-4.1

Vehicle design shall meet the following requirements:

(a) Vehicles used for bulk transportation of water gels shall meet the requirements of Chapter 5 and Section 3-6.

(b) Where electrical power is supplied by a self-contained motor-generator located on the vehicle, the generator shall be separated from the discharge point of the water gel.

(c) Processing equipment shall comply with 4-3.3 and 4-3.4.

(d) A positive action parking brake that sets the brakes on at least one axle shall be provided on vehicles equipped with air brakes. This brake shall be used during bulk delivery operations. Where required, wheel chocks shall be used.

4-4.2

Operation of bulk mixing and delivery vehicles shall meet the following requirements:

(a) The vehicle operator shall be trained in the safe operation of the vehicle and shall be knowledgeable of its mixing, conveying, and related equipment. The operator shall be familiar with the commodities being delivered and the general procedures for handling emergencies.

(b) No person shall smoke, carry matches or any flame-producing device, or carry any firearms while in or around bulk vehicles effecting the mixing, transfer, or down-the-hole loading of water gels at or near the blasting site.

(c) Caution shall be exercised in moving the vehicle within the blasting area to avoid driving the vehicle over or dragging hoses over firing lines, cap wires, or explosive materials. The driver shall obtain the assistance of a second person to guide the driver's movements while moving the vehicle.

(d) Material shall not be mixed while in transit.

(e) The location chosen for transferring the water gel or its ingredients from a support vehicle to the borehole-loading vehicle shall be away from the blast hole site where the boreholes are loaded or are in the process of being loaded.

4-5 Storage of Water Gels.

4-5.1

Water gels shall be stored as required by Chapter 6.

4-5.2

Where tests on specific formulations result in a Division 1.2 or Division 1.3 Explosives classification, bullet-resistant magazines shall not be required. (*See 6-2.4*.)

4-5.3

Semitrailer vans, trailer vans, or tanks used for the transportation of water gels shall be permitted for temporary storage of these materials, provided they are located in accordance with Table 6-4.1 with respect to inhabited buildings, passenger railways, and public highways, and in accordance with Table 6-4.2 with respect to each other. Trailers and semitrailers shall be provided with substantial means for locking, and the doors, hatches, and valves shall be kept locked. Locking mechanisms shall be as specified for Type 5 magazines. (*See 6-6.5*.)

Exception: Where stocks of water gels are actually being loaded or removed, the doors of trailers and semitrailers shall not be required to be locked.

Chapter 5 Transportation of Explosive Materials on Highways

5-1 Basic Requirements.

5-1.1

In addition to all other applicable requirements of this code, the transportation of explosive materials shall comply with U.S. Department of Transportation, Title 49, *Code of Federal Regulations*, "Hazardous Materials Regulations," Parts 100-179, and Title 49, *Code of Federal Regulations*, "Motor Carrier Safety Regulations," Part 397.

5-1.2

This chapter shall not apply to the transportation of small arms ammunition and components. (*See Chapter 11*.)

5-1.3

Explosive materials shall not be transported through any prohibited vehicular tunnel or subway or over any prohibited bridge, roadway, or elevated highway.

5-1.4

No person shall smoke or carry matches, flame-producing devices, or unauthorized firearms or cartridges while transporting explosive materials.

5-1.5

No person shall drive, load, or unload a motor vehicle transporting explosive materials in a careless or reckless manner.

5-1.6

Explosive materials shall not be carried or transported in or upon a public conveyance or vehicle carrying passengers for hire.

5-1.7

Explosive materials shall not be transferred from one vehicle to another without informing the local authority having jurisdiction. In the event of breakdown or collision, the local authority having jurisdiction shall be notified promptly to help safeguard such emergencies. Explosive materials shall be transferred from the disabled vehicle to another only where proper and qualified supervision is provided.

5-1.8

Detonators shall not be transported in the same vehicle with other Class 1 materials (Class A or Class B explosives).

Exception: As permitted by the U.S. Department of Transportation in Title 49, Code of Federal Regulations, Part 173.63.

5-2 Transportation Vehicles.

5-2.1

Vehicles used for transporting explosive materials shall be strong enough to carry the load and shall be in good mechanical condition.

5-2.2

Where explosive materials are transported on a vehicle with an open body, a portable magazine, securely fastened to the vehicle body, shall be used to store the explosive materials.

5-2.3

Vehicles used for transporting explosive materials shall have no exposed spark-producing surface on the inside of the body.

Exception: This requirement shall not apply to vehicles transporting blasting agents and oxidizing materials.

5-2.4

The floors of transportation vehicles shall be tight.

5-2.5

Motor vehicles used for transporting any quantity of explosive materials on public highways shall display all placards, lettering, or numbering required by the U.S. Department of Transportation.

5-2.6

Each motor vehicle used for transporting explosive materials shall be equipped with fire extinguishers in accordance with Table 5-2.6.

Table 5-2.6 Number of Extinguishers to Be Used According to Gross Vehicle Weight (GVW)

Trucks less than 14,000 lb (6350 kg)	At least 2 extinguishers having combined capacity of 4-A:20-B,C
Trucks 14,000 lb (6350 kg) or greater and tractor/semi-trailer units	At least 2 extinguishers having combined capacity of 4-A:70-B,C.

5-2.6.1 Only listed fire extinguishers shall be used. Fire extinguishers shall be designed, constructed, and maintained to allow a visual determination that extinguishers are fully charged.

5-2.6.2 Extinguishers shall be located where they are accessible for immediate use.

5-2.6.3 Extinguishers shall be examined and recharged periodically according to manufacturers' recommendations.

5-2.6.4 Where motor vehicles are operated in temperatures below 0°F (−17.8°C), dry chemical extinguishers shall be pressurized with nitrogen.

5-2.7

A motor vehicle used for transporting explosive materials shall be inspected to determine that it is in proper condition. The following items shall be verified:

(a) The fire extinguisher is filled and in working order.

(b) All electrical wiring is completely protected and securely fastened to prevent short-circuiting.

(c) The chassis, motor, oil pan, and body undersides are reasonably clean and free of excess oil and grease.

(d) The fuel tank and fuel lines are secure and free of leaks.

(e) The brakes, lights, horn, windshield wipers, and steering apparatus are functioning properly.

(f) The tires are inflated properly and free of defects.

(g) The vehicle is in the proper condition in every other respect and is acceptable for handling explosive materials.

5-2.8

Tires shall be checked for proper inflation and general condition after every 2 hours or 100 miles (161 km) of travel, whichever occurs first, and at every rest stop. Flat or overheated tires shall be removed from the vehicle immediately. After removal, the tire shall be placed far enough from the vehicle so that a spontaneous ignition of the tire does not endanger the vehicle or its cargo. The tire shall be cooled below the danger of ignition and the problem shall be corrected before it is replaced on the vehicle.

5-3 Operation of Transportation Vehicles.

5-3.1

Vehicles transporting explosive materials shall be driven by and be in the charge of only a properly licensed driver who is physically fit, careful, capable, reliable, and able to read and write the English language and who is not addicted to the use of, or under the influence of, intoxicants, narcotics, or other dangerous drugs.

5-3.2

The driver of a vehicle transporting explosive materials on public highways shall be not less than 21 years old. The driver shall be familiar with traffic regulations, applicable federal and state regulations concerning explosive materials, and the provisions of this chapter.

5-3.3

No vehicle transporting explosive materials shall be parked before reaching its destination, even while attended, on any public street adjacent to or in proximity to any bridge, tunnel, dwelling, building, or place where people work, congregate, or assemble.

Exception: This requirement shall not apply under emergency conditions.

5-3.4

Every motor vehicle transporting any quantity of Class A or B explosives shall, at all times, be attended by a driver or other qualified representative of the motor carrier operating the vehicle. This attendant shall have been made aware of the class of the explosive in the vehicle and its inherent dangers and shall have been instructed in the procedures to be followed in order to protect the public from those dangers. The attendant shall be familiar with the vehicle assigned and shall be provided with the training, necessary means, and authorization to move the vehicle where required.

5-3.5

For the purpose of this chapter, a motor vehicle shall be considered “attended” only when the driver or attendant is physically on or in the vehicle or when the vehicle is within his/her field of vision and the driver can reach it quickly and without interference. “Attended” also shall mean that the driver or attendant is awake, alert, and not engaged in other duties or activities that could divert attention from the vehicle.

Exception No. 1: This requirement shall not apply where communication with public officers or representatives of the shipper, carrier, or consignee or absence from the vehicle to obtain food or provide for physical comfort is necessary.

Exception No. 2: A vehicle carrying explosive materials shall be permitted to be left unattended, provided it is parked in an area where such parking is permitted, such as an area meeting the requirements of NFPA 498, Standard for Safe Havens and Interchange Lots for Vehicles Transporting Explosives.

5-3.6

No spark-producing metal or tools, oils, matches, firearms, electric storage batteries, flammable materials, acids, oxidizers, or corrosives shall be carried in the body of any motor vehicle transporting explosive materials.

Exception: Where permitted by the U.S. Department of Transportation "Hazardous Materials Regulations."

5-3.7

Vehicles transporting explosive materials shall avoid congested areas and heavy traffic. Where routes through congested areas have been designated by the authority having jurisdiction, such routes shall be followed.

5-3.8

Delivery shall be made only to authorized persons and into authorized magazines or approved temporary storage or handling areas.

Chapter 6 Aboveground Storage of Explosive Materials

6-1 Scope.

6-1.1

Explosive materials shall be kept in magazines meeting the requirements of this chapter.

6-1.2

This chapter shall not apply to the storage of small arms ammunition, propellant-actuated cartridges, small arms ammunition primers, and smokeless propellants. (*See Chapter 11*.)

6-2 Basic Requirements.

6-2.1

All explosive materials not in the process of manufacture, transportation, or use shall be kept in storage magazines.

6-2.2

Ammonium nitrate shall be permitted to be stored in the same magazine with blasting agents. Ammonium nitrate and blasting agents shall be permitted to be stored in the same magazine with other explosive materials. (*See 6-2.3*.)

6-2.2.1 Where ammonium nitrate is stored in the same magazine with blasting agents, the magazine shall be suitable for the storage of blasting agents.

6-2.2.2 Where ammonium nitrate is stored in the same magazine with explosives or with explosives and blasting agents, the magazine shall be suitable for the storage of explosives.

6-2.2.3 In determining the maximum quantity of explosive material that shall be permitted to be placed in a magazine, 1/2 the weight of the ammonium nitrate shall be added to the weight of the explosive material.

6-2.3

Detonators shall be stored in a separate magazine for blasting supplies and shall not be stored in a magazine with other explosive materials.

6-2.4

Explosive materials classified as Division 1.1 or Division 1.2 by the U.S. Department of Transportation shall be stored in Type 1, 2, or 3 magazines.

Exception: Black powder shall be permitted to be stored in a Type 4 magazine or a magazine of *higher classification (i.e., lower type number).*

6-2.5

Division 1.5 explosive materials (blasting agents) shall be permitted to be stored in a Type 5 magazine or a magazine of higher classification (i.e., lower type number).

6-3 Classification and Use of Magazines.

6-3.1

Outdoor magazines shall be classified and used in accordance with Table 6-3.1.

Table 6-3.1 Construction Features and Allowable Storage in Magazines

Classification and Use of Magazines/Construction Features	Magazine Types				
	1	2	3	4	5
Permanent	X			X	X
Portable		X	X	X	X
Bullet-resistant	X	X			
Fire-resistant	X	X	X	X[2]	X[2]
Theft-resistant	X	X	X	X	X[1]
Weather-resistant	X	X	X	X	X
Ventilated	X	X	X	X[2]	X[2]

[1] Each door of a mobile Type 5 magazine shall be equipped with at least one five-tumbler padlock having a $^3/_8$-in. (9.5-mm) case-hardened shackle. The lock shall not be required to be hooded.
[2] Over-the-road trucks or semitrailers used for temporary storage as Type 4 or Type 5 magazines shall not be required to be fire-resistant or ventilated.

Storage in Magazines	Magazine Types				
	1	2	3	4	5
High explosives (1.1 D) (Class A explosives) including dynamites; cap-sensitive emulsions; slurries and water gels; cast boosters	X	X	X		
Black powder (1.1 D) (Class A explosives); defined as	X	X	X	X	

low explosive by the BATF for storage					
Detonators (1.1 B) (Class A explosives)	X	X	X		
Detonating cords (1.1 D, 1.2 D, 1.4 G) (Class A or Class C explosives)	X	X	X		
Detonators (1.4 B, 1.4 S) (Class C explosives)	X	X	X	X	
Safety fuse, electric squibs, igniters, and igniter cord (1.4 G, 1.4 S)	X	X	X	X	
Blasting agents (1.5 D) (blasting agents)	X	X	X	X	X
Propellants (1.3 C) (Class B explosives); defined as low explosive by the BATF for storage	X	X	X	X	

NOTE 1: Detonators that are mass detonating shall not be stored in the same magazine with other explosive materials.
NOTE 2: Detonators that are not mass detonating shall be permitted to be stored with safety fuses, electric squibs, igniters, or igniter cord in Type 1, 2, 3, or 4 magazines.

6-3.2

Indoor magazines used for the storage of 50 lb (22.7 kg) or less of explosive materials in warehouses and in wholesale or retail establishments shall be fire-resistant and theft-resistant and shall be subject to the approval of the authority having jurisdiction.

6-4 Location of Magazines.

6-4.1

All outdoor magazines other than Type 3 shall be located to comply with the American Table of Distances for Storage of Explosives (ADT) or the Table of Distances for Storage of Low Explosives, as applicable. (*See Table 6-4.1 for the American Table of Distances. See Title 27, Code of Federal Regulations, Part 55, for the Table of Distances for Low Explosives*.)

Table 6-4.1 The American Table of Distances for Storage of Explosives
The American Table of Distances is reprinted from IME Safety Library Publication No. 2

with permission of the
Institute of Makers of Explosives, and was revised in June of 1991.

Quantity of Explosive Materials[1,2,3,4]		Distance in ft					
		Inhabited Buildings[9]		Public Highways Class A to D[11]		Passenger Railways — Public Highways with Traffic Volume More than 3000 Vehicles/Day[10	
Pounds Over	Pounds Not Over	Barricaded[6,7,8]	Unbarricaded	Barricaded[6,7,8]	Unbarricaded	Barricaded[6,7,8]	Unbarricad
0	5	70	140	30	60	51	102
5	10	90	180	35	70	64	128
10	20	110	220	45	90	81	162
20	30	125	250	50	100	93	186
30	40	140	280	55	110	103	206
40	50	150	300	60	120	110	220
50	75	170	340	70	140	127	254
75	100	190	380	75	150	139	278
100	125	200	400	80	160	150	300
125	150	215	430	85	170	159	318
150	200	235	470	95	190	175	350
200	250	255	510	105	210	189	378
250	300	270	540	110	220	201	402
300	400	295	590	120	240	221	442
400	500	320	640	130	260	238	476
500	600	340	680	135	270	253	506
600	700	355	710	145	290	266	532
700	800	375	750	150	300	278	556
800	900	390	780	155	310	289	578
900	1000	400	800	160	320	300	600
1000	1200	425	850	165	330	318	636
1200	1400	450	900	170	340	336	672
1400	1600	470	940	175	350	351	702

1600	1800	490	980	180	360	366	732
1800	2000	505	1010	185	370	378	756
2000	2500	545	1090	190	380	408	816
2500	3000	580	1160	195	390	432	864
3000	4000	635	1270	210	420	474	948
4000	5000	685	1370	225	450	513	1026
5000	6000	730	1460	235	470	546	1092
6000	7000	770	1540	245	490	573	1146
7000	8000	800	1600	250	500	600	1200
8000	9000	835	1670	255	510	624	1248
9000	10,000	865	1730	260	520	645	1290
10,000	12,000	875	1750	270	540	687	1374
12,000	14,000	885	1770	275	550	723	1446
14,000	16,000	900	1800	280	560	756	1512
16,000	18,000	940	1880	285	570	786	1572
18,000	20,000	975	1950	290	580	813	1626
20,000	25,000	1055	2000	315	630	876	1752
25,000	30,000	1130	2000	340	680	933	1866
30,000	35,000	1205	2000	360	720	981	1962
35,000	40,000	1275	2000	380	760	1026	2000
40,000	45,000	1340	2000	400	800	1068	2000
45,000	50,000	1400	2000	420	840	1104	2000
50,000	55,000	1460	2000	440	880	1140	2000
55,000	60,000	1515	2000	455	910	1173	2000
60,000	65,000	1565	2000	470	940	1206	2000
65,000	70,000	1610	2000	485	970	1236	2000
70,000	75,000	1655	2000	500	1000	1263	2000
75,000	80,000	1695	2000	510	1020	1293	2000
80,000	85,000	1730	2000	520	1040	1317	2000
85,000	90,000	1760	2000	530	1060	1344	2000
90,000	95,000	1790	2000	540	1080	1368	2000

95,000	100,000	1815	2000	545	1090	1392	2000
100,000	110,000	1835	2000	550	1100	1437	2000
110,000	120,000	1855	2000	555	1110	1479	2000
120,000	130,000	1875	2000	560	1120	1521	2000
130,000	140,000	1890	2000	565	1130	1557	2000
140,000	150,000	1900	2000	570	1140	1593	2000
150,000	160,000	1935	2000	580	1160	1629	2000
160,000	170,000	1965	2000	590	1180	1662	2000
170,000	180,000	1990	2000	600	1200	1695	2000
180,000	190,000	2010	2010	605	1210	1725	2000
190,000	200,000	2030	2030	610	1220	1755	2000
200,000	210,000	2055	2055	620	1240	1782	2000
210,000	230,000	2100	2100	635	1270	1836	2000
230,000	250,000	2155	2155	650	1300	1890	2000
250,000	275,000	2215	2215	670	1340	1950	2000
275,000	300,000	2275	2275	690	1380	2000	2000

Superscript numerals refer to explanatory footnotes.

Explanatory Notes Essential to the Application of the American Table of Distances for Storage of Explosives

NOTE 1: “Explosive materials” means explosives, blasting agents, and detonators.

NOTE 2: “Explosives” means any chemical compound, mixture, or device, the primary or common purpose of which is to function by explosion. A list of explosives determined to be within the coverage of Title 18, United States Code, Chapter 40, "Importation, Manufacture, Distribution and Storage of Explosive Materials,” is issued at least annually by the Director of the Bureau of Alcohol, Tobacco, and Firearms of the Department of the Treasury. For quantity and distance purposes, detonating cord of 50 grains per foot should be calculated as equivalent to 8 lb (3.7 kg) of high explosives per 1000 ft (305 m). Heavier or lighter core loads should be rated proportionately.

NOTE 3: “Blasting agents” means any material or mixture consisting of fuel and oxidizer, intended for blasting, and not otherwise defined as an explosive, provided that the finished product, as mixed for use or shipment, cannot be detonated by means of a No. 8 test blasting cap where unconfined.

NOTE 4: “Detonator” means any device containing any initiating or primary explosive that is used for initiating detonation. A detonator may not be permitted to contain more than 10 g of total explosives by weight, excluding ignition or delay charges. The term includes, but is not limited to, electric blasting caps of instantaneous and delay types, blasting caps for use with safety fuses, detonating cord delay connectors, and nonelectric instantaneous and delay blasting caps that use detonating cord, shock tube, or any other replacement for electric leg wires. All types of detonators in strengths through No. 8 cap should be rated at $1^1/_2$ lb (0.7 kg) of explosives per 1000 caps. For

strengths higher than No. 8 cap, the manufacturer should be consulted.
NOTE 5: "Magazine" means any building, structure, or container, other than an explosives manufacturing building, approved for the storage of explosive materials.
NOTE 6: "Natural barricade" means natural features of the ground, such as hills, or timber of sufficient density that the surrounding exposures that need protection cannot be seen from the magazine when the trees are bare of leaves.
NOTE 7: "Artificial barricade" means an artificial mound or revetted wall of earth of a minimum thickness of 3 ft (0.9 m).
NOTE 8: "Barricaded" means the effective screening of a building containing explosive materials from the magazine or another building, a railway, or a highway by a natural or an artificial barrier. A straight line from the top of any sidewall of the building containing explosive materials to the eave line of any magazine or other building or to a point 12 ft (3.7 m) above the center of a railway or highway shall pass through such barrier.
NOTE 9: "Inhabited building" means a building regularly occupied in whole or part as a habitation for human beings, or any church, schoolhouse, railroad station, store, or other structure where people are accustomed to assemble, but does not include any building or structure occupied in connection with the manufacture, transportation, storage, or use of explosive materials.
NOTE 10: "Railway" means any steam, electric, or other railroad or railway that carries passengers for hire.
NOTE 11: "Highway" means any public street, public alley, or public road.
NOTE 12: Where two or more storage magazines are located on the same property, each magazine shall comply with the minimum distances specified from inhabited buildings, railways, and highways, and, in addition, they should be separated from each other by not less than the distances shown for "separation of magazines," except that the quantity of explosive materials contained in detonator magazines shall govern with regard to the spacing of said detonator magazines from magazines containing other explosive materials. If any two or more magazines are separated from each other by less than the specified "separation of magazines" distances, such magazines, as a group, shall be considered as one magazine, and the total quantity of explosive materials stored in such group shall be treated as if stored in a single magazine located on the site of any magazine of the group, and shall comply with the minimum specified distances from other magazines, inhabited buildings, railways, and highways.
NOTE 13: Storage in excess of 300,000 lb (136,200 kg) of explosive materials in one magazine generally is not necessary for commercial enterprises.
NOTE 14: This table applies only to the manufacture and permanent storage of commercial explosive materials. It is not applicable to the transportation of explosives or any handling or temporary storage necessary or incident thereto. It is not intended to apply to bombs, projectiles, or other heavily encased explosives.
NOTE 15: Where a manufacturing building on an explosive materials plant site is designed to contain explosive materials, the building shall be located at a distance from inhabited buildings, public highways, and passenger railways in accordance with the American Table of Distances based on the maximum quantity of explosive materials permitted to be in the building at one time.

6-4.2

Blasting agent manufacturing plants and storage of blasting agents and ammonium nitrate shall be located in compliance with the Table of Recommended Separation Distances of Ammonium Nitrate and Blasting Agents (SDT) as well as with the American Table of Distances. (*See Tables 6-4.1 and 6-4.2*.)

Table 6-4.2 Table of Recommended Separation Distances of Ammonium Nitrate and Blasting Agents from Explosives or Blasting Agents[1,6]

Donor Weight		Minimum Separation Distance of Acceptor when Barricaded[2] (ft)		Minimum Thickness of Artificial Barricades[5]
Pounds	Pounds	Ammonium	Blasting	

Over	Not Over	Nitrate[3]	Agent[4]	(in.)
	100	3	11	12
100	300	4	14	12
300	600	5	18	12
600	1000	6	22	12
1000	1600	7	25	12
1600	2000	8	29	12
2000	3000	9	32	15
3000	4000	10	36	15
4000	6000	11	40	15
6000	8000	12	43	20
8000	10,000	13	47	20
10,000	12,000	14	50	20
12,000	16,000	15	54	25
16,000	20,000	16	58	25
20,000	25,000	18	65	25
25,000	30,000	19	68	30
30,000	35,000	20	72	30
35,000	40,000	21	76	30
40,000	45,000	22	79	35
45,000	50,000	23	83	35
50,000	55,000	24	86	35
55,000	60,000	25	90	35
60,000	70,000	26	94	40
70,000	80,000	28	101	40
80,000	90,000	30	108	40
90,000	100,000	32	115	40
100,000	120,000	34	122	50
120,000	140,000	37	133	50
140,000	160,000	40	144	50

160,000	180,000	44	158	50
180,000	200,000	48	173	50
200,000	220,000	52	187	60
220,000	250,000	56	202	60
250,000	275,000	60	216	60
275,000	300,000	64	230	60

For SI Units: 1 lb = 0.454 kg; 1 ft = 0.305 m; 1 in. = 2.54 cm

Notes to Table of Recommended Separation Distances of Ammonium Nitrate and Blasting Agents from Explosives or Blasting Agents

NOTE 1: Recommended separation distances are to prevent explosion of ammonium nitrate and ammonium nitrate-based blasting agents by propagation from nearby stores of high explosives or blasting agents referred to in the table as the "donor." Ammonium nitrate, by itself, is not considered to be a donor where applying this table. Ammonium nitrate, ammonium nitrate-fuel oil, or combinations thereof are acceptors. If stores of ammonium nitrate are located within the sympathetic detonation distance of explosives or blasting agents, 1/2 the mass of the ammonium nitrate shall be included in the mass of the donor.

NOTE 2: Where the ammonium nitrate or blasting agent, or both, is not barricaded, the distances shown in the table shall be multiplied by 6. These distances allow for the possibility of high velocity metal fragments from mixers, hoppers, truck bodies, sheet metal structures, metal containers, and the like that could enclose the donor. Where storage is in bullet-resistant magazines1 recommended for explosives or where the storage is protected by a bullet-resistant wall, distances and barricade thicknesses in excess of those prescribed in the American Table of Distances are not required.

NOTE 3: The distances in the table apply to ammonium nitrate that passes the insensitivity test prescribed in the definition of ammonium nitrate fertilizer promulgated by the Fertilizer Institute;2 ammonium nitrate failing to pass said test shall be stored at separation distances determined by competent persons and approved by the authority having jurisdiction.

NOTE 4: These distances apply to blasting agents that pass the insensitivity test prescribed in regulations of the U.S. Department of Transportation and the U.S. Department of the Treasury, Bureau of Alcohol, Tobacco, and Firearms.

NOTE 5: Earth, sand dikes, or enclosures filled with the prescribed minimum thickness of earth or sand shall be permitted to be used as artificial barricades. Natural barricades, such as hills or timber of sufficient density that the surrounding exposures that need protection cannot be seen from the donor when the trees are bare of leaves, also shall be permitted to be used.

NOTE 6: For determining the distances to be maintained from inhabited buildings, passenger railways, and public highways, Table 6-4.1, the American Table of Distances for Storage of Explosives, shall be used.

[1]For construction of bullet-resistant magazines, see Appendix C.

[2]*Definition and Test Procedures for Ammonium Nitrate Fertilizer,* Fertilizer Institute, November 1964.

6-4.3

The separation distances provided by the American Table of Distances or the Table of Recommended Separation Distances, or both, shall be used to determine minimum separation of storage facilities for explosives, blasting agents, and ammonium nitrate. The tables to be used shall be as specified in Table 6-4.3.

Table 6-4.3 Application of Separation Distance Tables

Type of Donor	Type of Acceptor	Table	Distances Listed Under
Explosives	Explosives	ATD	Separation of magazines
Explosives	Ammonium nitrate	SDT	Ammonium nitrate
Explosives	Blasting agent	SDT	Blasting agent
Blasting agent	Explosives	ATD	Separation of magazines
Blasting agent	Blasting agent	SDT	Blasting agent
Blasting agent	Ammonium nitrate	SDT	Ammonium nitrate

6-4.4

An indoor magazine shall be located only on a floor that has an entrance at or a ramp to grade level. It shall be located no more than 10 ft (3 m) from the entrance. It shall be located as approved by the authority having jurisdiction to facilitate rapid removal in an emergency.

6-4.5

Two magazines shall be permitted to be located in the same building, provided one magazine is used solely for the storage of detonators in quantities not exceeding 5000. A distance of 10 ft (3 m) shall be maintained between the magazines.

6-4.6

The local fire department and other local emergency response agencies shall be notified of the location of all magazines and shall be notified of any changes in location.

6-4.7

Type 3 magazines shall be located as far away as practicable from neighboring inhabited buildings, railways, highways, and other magazines.

6-4.8

Type 3 magazines shall be attended where explosive materials are stored within. All explosive materials shall be removed to appropriate storage magazines for unattended storage at the end of the work day.

6-4.9

Two Type 3 magazines shall be permitted to be located at a blasting site, provided one magazine is used solely for the storage of detonators.

6-4.10

A Type 5 magazine shall not be located in a residence or dwelling.

6-5 Magazine Construction — Basic Requirements.

6-5.1

Magazines shall be constructed to comply with Section 6-5 or in a manner substantially equivalent to the requirements for safety and security embodied in this section.

6-5.2

The ground in the vicinity of magazine shall be graded so that water drains away from the magazine.

6-5.3

Heated magazines shall be heated by either hot water radiant heating within the magazine building or by indirect warm air heating.

6-5.4

Indirect warm air shall be heated by either hot water or low pressure [15 psig (103 kPa) or less] steam coils located outside the magazine building.

6-5.5

Magazine heating systems shall meet the following requirements:

(a) Radiant heating coils within the building shall be installed so that explosive materials or their containers cannot contact the coils and so that air is free to circulate between the coils and the explosive materials. The surface temperature of the coils shall not exceed 165°F (74°C).

(b) Heating ducts shall be installed so that the hot air discharged from the ducts is not directed against explosive materials or containers.

(c) The heating system shall be controlled so that the ambient temperature of the magazine does not exceed 130°F (54°C).

(d) Any electric fan or pump used in the heating system shall be located outside the magazine, separate from the magazine walls, and shall be grounded.

(e) Any electric motor and any controls for electric heating devices used to heat water or produce steam shall have overload devices and disconnects that comply with NFPA 70, *National Electrical Code*. All electrical switch-gear shall be located at least 25 ft (7.6 m) from the magazine.

(f) Any fuel-fired heating source for the hot water or steam shall be separated from the magazine by a distance of not less than 25 ft (7.6 m). The area between the heating unit and the magazine shall be cleared of all combustible material.

(g) Explosive materials stored in magazines shall be arranged so that uniform circulation of air is ensured.

6-5.6

Where lighting is necessary within the magazine, electric safety flashlights or electric safety lanterns shall be used.

6-5.6.1 Electric lighting shall be permitted to be used within a magazine, provided the installation meets the following requirements:

(a) Junction boxes containing fuses or circuit breakers and electrical disconnects shall be located at least 25 ft (7.6 m) from the magazine.

(b) Disconnects, fuses, and circuit breakers shall be protected by a voltage surge arrester capable of handling 2500 amperes for 0.1 seconds.

(c) All wiring from switches, both inside and outside the magazine, shall be installed in rigid conduit. Wiring leading to the magazine shall be installed underground.

(d) Conduit and light fixtures inside the magazine shall be protected from physical damage by suitable guards or by their location.

(e) Light fixtures shall be suitably enclosed to prevent sparks or hot metal from falling onto the floor or onto material stored in the magazine.

(f) Junction boxes located within the magazine shall have no openings and shall be equipped with close-fitting covers.

(g) Magazines containing explosive materials that could release flammable vapors shall have wiring and fixtures that meet the requirements of NFPA 70, *National Electrical Code*, Article 501.

(h) Lights inside magazines shall not be left on while the magazine is unattended.

6-5.7

There shall be no exposed ferrous metal on the interior of a magazine where it has the potential to contact packages of explosives.

Exception: This requirement shall not apply to Type 5 magazines.

6-6 Magazine Construction — Requirements for Specific Types.

6-6.1 Type 1 Magazines.

A Type 1 magazine shall be a permanent structure, such as a building or igloo, that is bullet-resistant, fire-resistant, theft-resistant, weather-resistant, and ventilated.

(a) Walls and doors shall be bullet-resistant and shall be permitted to be constructed in accordance with any of the specifications in Appendix C.

(b) The roof shall be permitted to be constructed of any type of structurally sound materials that are or have been made fire-resistant on the exterior.

(c)* Where the natural terrain around a Type 1 magazine makes it possible for a bullet to be shot through the roof and ceiling at such an angle that the bullet can strike the explosive materials within, the roof or the ceiling shall be of bullet-resistant construction.

(d) The foundation shall be permitted to be of masonry, wood, or metal and shall be enclosed completely. A wood foundation enclosure shall be covered on the exterior with metal of not less than 26-gauge thickness.

Exception: Openings to provide cross ventilation shall not be required to be enclosed.

(e) The floor shall be constructed of wood or other suitable material. Floors constructed of materials that could cause sparks shall be covered with a nonsparking surface, or the packages of explosive materials shall be placed on pallets of nonsparking material.

(f) Type 1 magazines shall be ventilated to prevent dampness or heating of explosive materials. Ventilation openings shall be screened to prevent the entrance of sparks. Ventilators in sidewalls shall be offset or shielded. Magazines having foundation and roof ventilators, with the air circulating between the sidewalls and floor and between the sidewalls and ceiling, shall have a wood lattice lining or equivalent means to prevent packages of explosive materials from being stacked against the sidewalls and blocking air circulation. A 2-in. (51-mm) air space shall be provided between the sidewalls and the floor.

(g) Each door of a Type 1 magazine shall be equipped with one of the following locking systems:

1. Two mortise locks;

2. Two padlocks in separate hasps and staples;

3. A mortise lock and a padlock;

4. A mortise lock that requires two keys to open; or

5. A three-point lock or an equivalent lock that secures the door to the frame at more than one point.

Padlocks shall be steel, shall have at least five tumblers, and shall have at least a $^{3}/_{8}$-in. (9.5-mm) case-hardened shackle. All padlocks shall be protected by steel hoods installed to discourage the insertion of bolt cutters. Doors secured by a substantial internal bolt shall not require additional locking devices. Hinges and hasps shall be fastened securely to the magazine, and all locking hardware shall be secured rigidly and directly to the door frame.

6-6.2 Type 2 Magazines.

A Type 2 magazine shall be a portable or mobile structure, such as a box, skid-magazine, trailer, or semitrailer that is fire-resistant, theft-resistant, weather-resistant, and ventilated. Where used for outdoor storage, Type 2 magazines also shall be bullet-resistant.

6-6.2.1 Type 2 Outdoor Magazines.

(a) The walls and roof or ceiling shall be constructed in accordance with the provisions of 6-6.1(a), (b), and (c).

(b) Doors shall be of metal, constructed in accordance with the provisions of 6-6.1(a), or shall have a metal exterior with an inner door meeting the provisions of 6-6.1(a).

(c) Floors constructed of ferrous metal shall be covered with a nonsparking surface.

(d) A top-opening magazine shall have a lid that overlaps the sides by at least 1 in. (25.4 mm) when in the closed position.

(e) The magazine shall be supported so that its floor does not directly contact the ground.

(f) Magazines of less than 1 yd^3 (0.766 m^3) shall be fastened securely to a fixed object to prevent theft of the entire magazine.

(g) Hinges, hasps, locks, and locking hardware shall comply with 6-6.1(g).

Exception: Padlocks on vehicular magazines shall not be required to be protected by steel *hoods.*

(h) Whenever a vehicular magazine is left unattended, its wheels shall be removed, its kingpins shall be locked, or it otherwise shall be effectively immobilized.

6-6.2.2 Type 2 Indoor Magazines.

(a) The magazine shall have substantial wheels or casters to facilitate its removal from the building in case of emergency.

(b) The cover of the magazine shall have substantial strap hinges and a means for locking. The magazine shall be kept locked with a five-tumbler padlock or its equivalent.

Exception: The magazine shall be permitted to be unlocked during placement or removal of explosive materials.

(c) The magazine shall be painted red, and the top shall bear the words "Explosives — Keep Fire Away" in white letters at least 3 in. (76 mm) high.

(d) Type 2 indoor magazines constructed of wood shall have sides, bottoms, and covers or doors constructed of 2-in. (51-mm) hardwood that are well braced at corners. The magazines shall be covered with sheet metal of not less than 26 gauge. Nails exposed to the interior of the magazines shall be countersunk.

(e) Type 2 indoor magazines constructed of metal shall be of 12-gauge sheet metal and shall be lined with a nonsparking material. The edges of metal covers shall overlap the side by at least 1 in. (25.4 mm).

6-6.3 Type 3 Magazines.

A Type 3 magazine is a "day box" or portable structure used for the temporary storage of explosive materials. A Type 3 magazine shall be fire-resistant, theft-resistant, and weather-resistant.

(a) The magazine shall be equipped with one steel padlock (which shall not be required to be protected by a steel hood) having at least five tumblers and a case-hardened steel shackle at least $^{3}/_{8}$ in. (9.5 mm) in diameter. Doors shall overlap the sides by at least 1 in. (25.4 mm). Hinges and hasps shall be attached by welding, riveting, or bolting (nuts on inside).

(b) The magazine shall be constructed of not less than 12-gauge [0.1046-in. (2.66-mm)] steel, lined with at least $^{1}/_{2}$-in. (12.7-mm) plywood or $^{1}/_{2}$-in. (12.7-mm) masonite type hardboard.

(c) Type 3 magazines containing explosive materials shall be within line-of-site vision of a blaster.

6-6.4 Type 4 Magazines.

A Type 4 magazine shall be a permanent, portable, or mobile structure such as a building, igloo, box, semitrailer, or other mobile container that is fire-resistant, theft-resistant, and weather-resistant.

6-6.4.1 Type 4 Outdoor Magazine.

(a) A Type 4 outdoor magazine shall be constructed of masonry and wood covered with sheet metal, fabricated metal, or a combination of these materials. Doors shall be metal or wood covered with metal.

(b) Permanent Type 4 magazines shall comply with 6-6.1(d), (f), and (g).

(c) Vehicular Type 4 magazines shall comply with 6-6.2.1(g) and shall be immobilized while unattended, as described in 6-6.2.1(h).

6-6.4.2 Type 4 Indoor Magazine. A Type 4 indoor magazine shall comply with all provisions of 6-6.2.2.

6-6.5 Type 5 Magazines.

A Type 5 magazine shall be a permanent, portable, or mobile structure such as a building, igloo, box, bin, tank, semitrailer, bulk trailer, tank trailer, bulk truck, tank truck, or other mobile container that is theft-resistant. No ventilation shall be required, and ferrous metal shall not be required to be covered with nonsparking material.

6-6.5.1 Type 5 Outdoor Magazine.

(a) A Type 5 permanent outdoor magazine shall be weather-resistant and shall be locked with at least one steel five-tumbler padlock having at least a $^3/_8$-in. (9.5-mm) case-hardened shackle. A hood for the padlock shall not be required.

(b) Hinges and hasps shall be fastened securely to the magazine and all locking hardware shall be secured rigidly and directly to the door frame.

(c) A vehicular Type 5 magazine shall be immobilized while unattended as described in 6-6.2.1(h).

6-6.5.2 Type 5 Indoor Magazine. A Type 5 indoor magazine shall be constructed in accordance with the requirements for Type 5 outdoor magazines.

Exception: A Type 5 indoor magazine shall not be required to be weather-resistant.

6-7 Storage within Magazines.

6-7.1

Magazines shall be supervised by a competent person at all times. This person shall be at least 21 years old and shall be responsible for the enforcement of all safety precautions.

6-7.2

All magazines containing explosive materials shall be opened and inspected at maximum intervals of 3 days to determine whether there has been unauthorized or attempted entry into the magazines or whether there has been unauthorized removal of the magazines or their contents.

6-7.3

Magazine doors shall be kept locked.

Exception: Magazine doors shall be permitted to be unlocked during placement or removal of explosives or during inspection.

6-7.4

Safety rules covering the operations of magazines shall be posted on the interior side of the magazine door.

6-7.5

Where explosive materials are removed from the magazine for use, the oldest stock shall be used first.

6-7.6

Corresponding grades and brands of explosive materials shall be stored together so that brand and grade markings are readily visible. All stocks shall be stored in a manner that allows them to be easily counted and checked.

6-7.7

Containers of explosive materials shall be piled in a stable manner and laid flat with the top side up.

6-7.8

Open containers of explosive materials shall be closed securely before being returned to a magazine. No container without a closed lid shall be permitted to be stored in the magazine. Only fiberboard containers shall be permitted to be opened in the magazine.

6-7.9

Containers of explosive materials other than fiberboard shall not be unpacked or repacked inside or within 50 ft (15.25 m) of a magazine or in close proximity to other explosive materials.

6-7.10

Tools used for opening containers of explosive materials shall be constructed of nonsparking material.

Exception: Metal slitters shall be permitted to be used for opening fiberboard containers.

6-7.11

Magazines shall be used exclusively for the storage of explosive materials, blasting materials, and blasting accessories. Metal tools other than nonferrous transfer conveyors shall not be stored in a magazine containing explosives or detonators.

Exception: Ferrous metal conveyor stands protected by a coat of paint shall be permitted to be stored within a magazine.

6-7.12

Magazine floors shall be regularly swept and kept clean, dry, and free of grit, paper, empty packages, and rubbish. Brooms and other cleaning utensils shall not have any spark-producing metal parts. Sweepings from magazine floors shall be disposed of in accordance with the manufacturers' instructions.

6-7.13

Where any explosive material has deteriorated to the extent that it is in an unstable or dangerous condition or if nitroglycerine or other liquid is leaking from any explosive, the person responsible for the explosives shall contact the manufacturer for assistance immediately. Magazine floors stained with nitroglycerine or other liquid shall be cleaned in accordance with the manufacturers' instructions.

6-7.14

Before making repairs to the interior of a magazine, all explosive materials shall be removed and the floor shall be cleaned.

6-7.15

In making repairs that could result in sparks or fire to the exterior of a magazine, all explosive materials shall be removed.

6-7.16

Explosive materials removed from a magazine undergoing repair shall be placed either in another magazine or at a safe distance from the magazine. They shall be guarded and protected properly. Upon completion of the repairs, they shall be returned to the magazine promptly.

6-8 Miscellaneous Safety Precautions.

6-8.1

Smoking, matches, open flames, spark-producing devices, and firearms shall not be permitted inside of or within 50 ft (15.25 m) of a magazine.

Exception: Firearms carried by authorized guards.

6-8.2

The area around a magazine shall be kept clear of brush, dried grass, leaves, and similar combustibles for a distance of at least 25 ft (7.63 m).

6-8.3

Combustible materials shall not be stored within 50 ft (15.25 m) of magazines.

6-8.4

Explosive materials recovered from blasting misfires shall be stored in a separate magazine until disposal instructions have been received from the manufacturer. Such explosive materials then shall be disposed of in the manner recommended by the manufacturer. Detonators recovered from blasting misfires shall not be reused.

6-8.5

Property on which Type 1 magazines and outdoor magazines of Types 2, 4, and 5 are located shall be posted with signs reading “Explosives — Keep Off.” Such signs shall be located to minimize the possibility that a bullet shot at the sign hits the magazine.

6-8.6

Where Division 1.5 Explosives are stored in an over-the-road trailer Type 5 storage magazine, it shall be placarded with an approved U.S. Department of Transportation placard for Division 1.5 Explosives until it is empty.

Chapter 7 Use of Explosive Materials for Blasting

7-1 Basic Requirements.

7-1.1

All federal, state, and local laws and regulations applicable to obtaining, owning, transporting, storing, handling, and using explosive materials shall be followed.

7-1.2

Explosive materials shall be protected from unauthorized possession and shall not be abandoned.

7-1.3

Explosive materials shall be used only by experienced persons who are familiar with the hazards involved and who hold all required permits.

7-1.3.1 Loading and firing shall be performed or supervised only by a person possessing an appropriate blaster's permit.

7-1.3.2 Trainees, helpers, and other persons who do not hold the required permits shall work only under the supervision of persons holding such permits.

7-1.4

No explosive materials shall be located or stored where they have the potential to be exposed to flame, excessive heat, sparks, or impact.

7-1.4.1 No firearms shall be discharged into or in the vicinity of a vehicle containing explosive materials or into or in the vicinity of a location where explosive materials are being handled, used, or stored.

7-1.4.2 No smoking shall be permitted within 50 ft (15.25 m) of any location where explosives are being handled or used.

7-1.4.3 No person within 50 ft (15.25 m) of any location where explosives are being handled or used shall carry any matches, open light, or other fire or flame.

Exception: This requirement shall not apply to suitable devices for lighting safety fuses.

7-1.5

No person under the influence of intoxicating beverages, narcotics, or other dangerous drugs shall be permitted to handle explosive materials.

7-1.6

No attempt shall be made to fight a fire that cannot be contained or controlled before it reaches explosive materials. In such cases, all personnel shall be evacuated immediately to a safe location, and the area shall be guarded from entry by spectators or intruders.

7-1.7

Unauthorized or unnecessary personnel shall not be present where explosive materials are being handled, used, or stored.

7-1.8

Explosive materials shall be kept in closed containers or packages while being transported between the storage magazine and the blasting site.

Exception: Partial reels of detonating cord shall not be required to be kept in closed containers, unless transported over public highways.

7-1.9

Containers of explosive materials shall not be opened in any magazine or within 50 ft (15.25 m) of any magazine.

Exception: This requirement shall not apply to explosive materials in fiberboard containers.

7-1.10

Nonsparking tools shall be used for opening any package or container of explosive materials.

Exception: Metal slitters shall be permitted to be used for opening fiberboard containers.

7-1.11

No blasting operation shall be performed in a manner contrary to the instructions of the manufacturer of the explosive materials being used.

7-1.12

Where blasting is done in a congested area or in close proximity to a structure, railway, or highway, or any other installation that could be affected, special precautions shall be taken to prevent damage and to minimize earth vibrations and air blast effects. Blasting mats or other protective devices shall be used to prevent fragments from being thrown.

7-1.13

Persons authorized to prepare explosive charges or to conduct blasting operations shall use every reasonable precaution including, but not limited to, warning signals, flags, barricades, mats, or other equally effective means to ensure the safety of the general public and workers.

7-1.14

Surface blasting operations shall be conducted during daylight hours only.

Exception: This requirement shall not apply where approved by the authority having jurisdiction.

7-1.15

Where blasting is conducted in the vicinity of utility lines or rights-of-way, the blaster shall notify the appropriate representatives of the utilities at least 24 hours in advance of blasting, specifying the location and the intended time of such blasting. Verbal notice shall be confirmed with written notice.

Exception: In an emergency situation, this time limit shall be permitted to be waived by the authority having jurisdiction.

7-1.16

Precautions shall be taken to prevent accidental discharge of electric detonators from currents induced by radar and radio transmitters, lightning, adjacent power lines, dust and snow storms, or other sources of extraneous electricity. These precautions shall include:

(a) The posting of signs warning against the use of mobile radio transmitters on all roads within 350 ft (107 m) of blasting operations.

(b)* Observance of the latest recommendations with regard to blasting in the vicinity of radio transmitters or power lines.

(c) The discontinuance of surface use, underground use, and all handling of explosive materials during the approach of and for the duration of an electrical storm. All personnel shall move to a safe location.

(d) Consideration to the fact that lightning has been known to follow steel, piping, and conductive ore into underground mines.

7-1.17

Precautions shall be taken to prevent accidental initiation of nonelectric detonators from stray currents induced by lightning or static electricity.

7-2 Preblast Operations.

7-2.1

During the time that holes are being loaded or are loaded with explosive materials, blasting agents, or detonators, the blast site shall be off limits to all but those persons authorized to engage in the drilling and loading operations or who are otherwise authorized to enter the site. The blast site shall be guarded or barricaded and posted.

7-2.2

Drill holes shall be large enough to allow free insertion of cartridges of explosive materials. Drill holes shall not be collared in bootlegs or in holes that previously contained explosive materials. Holes shall not be drilled where there is a danger of intersecting another hole containing explosive material.

7-2.3

All drill holes shall be inspected and cleared of any obstruction before loading.

7-2.4

Pneumatic loading of blasting agents into blast holes primed with electric detonators or other static-sensitive initiation systems shall comply with the following requirements:

(a) A positive grounding device shall be used for the equipment to prevent the accumulation of static electricity.

(b) A semiconductive discharge hose shall be used.

(c) A qualified person shall evaluate all systems to ensure that they adequately dissipate static charges under field conditions.

7-2.5

Tamping shall be performed only with wooden rods or approved plastic poles having no exposed metal parts.

Exception: Nonsparking metal connectors shall be permitted to be used on jointed tamping poles.

7-2.5.1 Violent tamping shall be avoided.

7-2.5.2 The primer shall not be tamped at any time.

7-2.6

After the loading for a blast is completed and before firing, all excess explosive materials shall be removed from the area and returned to the proper storage facilities.

7-2.7

As soon as practicable after all blast holes are connected, prior to connecting to a source of initiation such as a blasting machine, and continuing until the shot has been fired and subjected to post-blast examination, the blast area shall be guarded or barricaded and posted.

7-3 Initiating Blasts.

7-3.1

Cap and fuse shall not be used to initiate blasts in congested areas or on or adjacent to highways open to traffic.

7-3.2

Where a safety fuse is used, the burning rate shall be determined and in no case shall fuse lengths of less than 120 seconds be used. The detonator shall be attached securely to the fuse with a standard ring-type cap crimper.

7-3.3

Where electric detonators are used, stray current tests shall be made as frequently as necessary. Maximum stray current shall not exceed 0.05 amperes through a 1-ohm resistor, measured at the blast site. Nonelectric initiating systems shall be used unless corrective action is taken to reduce the stray current below the limits indicated in this paragraph.

7-3.4

Electric detonators of different brands shall not be used in the same firing circuit.

7-3.5

All electric blasting circuits and other initiating systems whose continuity can be tested (such as gas detonator initiating systems) shall be tested with a blasting galvanometer or other blast continuity test instrument, as appropriate, that has been designed and approved for the purpose. All electrically initiated blasts shall be made by using blasting machines suitable for the circuitry being fired.

7-3.6

No detonator shall be inserted in explosive materials that do not have a cap well without first making a hole in the cartridge with a proper size nonsparking tool or the appropriate pointed handle of an approved cap crimper.

7-3.6.1 Primers shall not be assembled closer than 50 ft (15.25 m) from any magazine. Primers shall be assembled only when and as necessary for immediate needs.

7-3.6.2 Adequate priming shall be used. If any uncertainty exists regarding the amount of priming necessary, the manufacturer shall be consulted.

7-3.6.3 Primers shall be assembled only at the time of use and as close to the blast site as conditions allow.

7-3.6.4 Where using nonelectric initiation systems:

(a) The selection of the initiation system and the design of the blast shall be under the supervision of the blaster in charge;

(b) The initiation system shall be used in accordance with the manufacturer’s instructions;

(c) The blaster in charge shall conduct a visual check after blast hookup;

(d) The blast layout shall be tested for continuity as recommended by the manufacturer where using a system that can be tested for continuity; and

(e) A double trunk line or closed-loop hookup shall be used where judged to be necessary by the blaster in charge.

7-3.7

Only the person making the lead line connections or the blaster in charge shall fire the blast. All connections shall be made progressively from the borehole back to the initiation point. Blasting lead lines shall remain shunted (shorted) and shall not be connected to the blasting machine or other source of current until the blast is to be fired.

7-3.8

No blast shall be fired until the blaster in charge has made certain that all surplus explosive materials are in a safe place, all persons and equipment are at a safe distance or under sufficient cover, and an adequate warning signal has been given.

7-4 Procedures after Blasting.

7-4.1

No person shall return to the blast area until permitted to do so by the blaster.

7-4.2

The blaster shall allow sufficient time for smoke and fumes to dissipate and for dust to settle before returning to the blast site.

7-4.3

The blaster shall inspect the entire blast site for misfires before allowing other personnel to return to the blast area.

7-5 Misfires.

7-5.1

Where a misfire is found, the blaster shall provide the proper safeguards for excluding all personnel from the blast area. Misfires shall be reported to the supervisor immediately.

7-5.2

No additional work, other than that necessary to remove the hazard, shall be performed. Only those persons needed to do such work shall remain at the blast site.

7-5.3

No attempt shall be made to extract explosive materials from a misfired hole. A new primer shall be inserted, and the hole shall be reblasted.

Exception: Where reblasting presents a hazard, the explosive materials shall be permitted to be washed out with water, or, where the misfire is under water, blown out with air.

7-5.4

Where there are misfires using cap and fuse, all personnel shall stay clear of the blast site for at least 1 hour.

7-5.5

Where there are misfires using other nonelectric detonators (i.e., other than cap and fuse) or using electric detonators, all personnel shall stay clear of the blast site for at least 30 minutes.

7-5.6

Misfires shall be the responsibility of the person in charge of the blasting operation.

7-5.7

Where a misfire is suspected, all initiating circuits (electric or nonelectric) shall be traced carefully and a search made for unexploded charges.

7-5.8

No drilling, digging, or picking shall be permitted until all misfires have been detonated or until the authority having jurisdiction approves the resumption of work.

7-6 Disposal of Explosive Materials.

7-6.1

Empty containers and paper and fiber packing materials that previously contained explosive materials shall be disposed of or reused in an approved manner.

7-6.2

All personnel shall remain at a safe distance from the disposal area.

7-6.3

All explosive materials that are obviously deteriorated or damaged shall not be used and shall be destroyed in accordance with the requirements of 6-7.13.

7-6.4*

In the event that it becomes necessary to destroy any explosives, either because of damage to containers, deterioration, or any other reason, all handling of explosives shall cease and the manufacturer shall be contacted for assistance immediately. The manufacturer's advice shall be followed without deviation.

Chapter 8 Ground Vibration, Airblast, Flyrock

8-1 Ground Vibration.

8-1.1

At all blasting operations, the maximum ground vibration at any dwelling, public building, school, church, or commercial or institutional building adjacent to the blasting site shall not exceed the limitations specified in Table 8-1.1.

Exception: As otherwise authorized or restricted by the authority having jurisdiction.

Table 8-1.1 Peak Particle Velocity Limits

Distance from Blasting Site	Maximum Allowable Peak Particle Velocity[1]
0 ft to 300 ft (0 m to 91.4 m)	1.25 in./sec (31.75 mm/s)

301 ft to 5000 ft (91.5 m to 1524 m)	1.00 in./sec (25.4 mm/s)
5001 ft (1525 m) and over	0.75 in./sec (19 mm/s)

[1]Peak particle velocity shall be measured in three (3) mutually perpendicular directions, and the maximum allowable limits shall apply to each of these measurements.

8-1.2 Frequency Versus Particle Velocity Graphs.

In lieu of Table 8-1.1, a blasting operation shall have the option to use the graphs shown in either Figure 8-1.2(a) or (b) to limit peak particle velocity based upon the frequency of the blast vibration. If either graph in Figure 8-1.2(a) or (b) is used to limit vibration levels, the methods for monitoring vibration and calculating frequency shall be approved by the authority having jurisdiction.

8-1.3 Scaled Distance Equations.

Unless a blasting operation uses a seismograph to monitor a blast to ensure compliance with Table 8-1.1 or Figure 8-1.2(a) or (b), or has been granted special permission by the authority having jurisdiction to utilize a modified scaled distance factor, the operation shall comply with the scaled distance equations shown in Table 8-1.3.

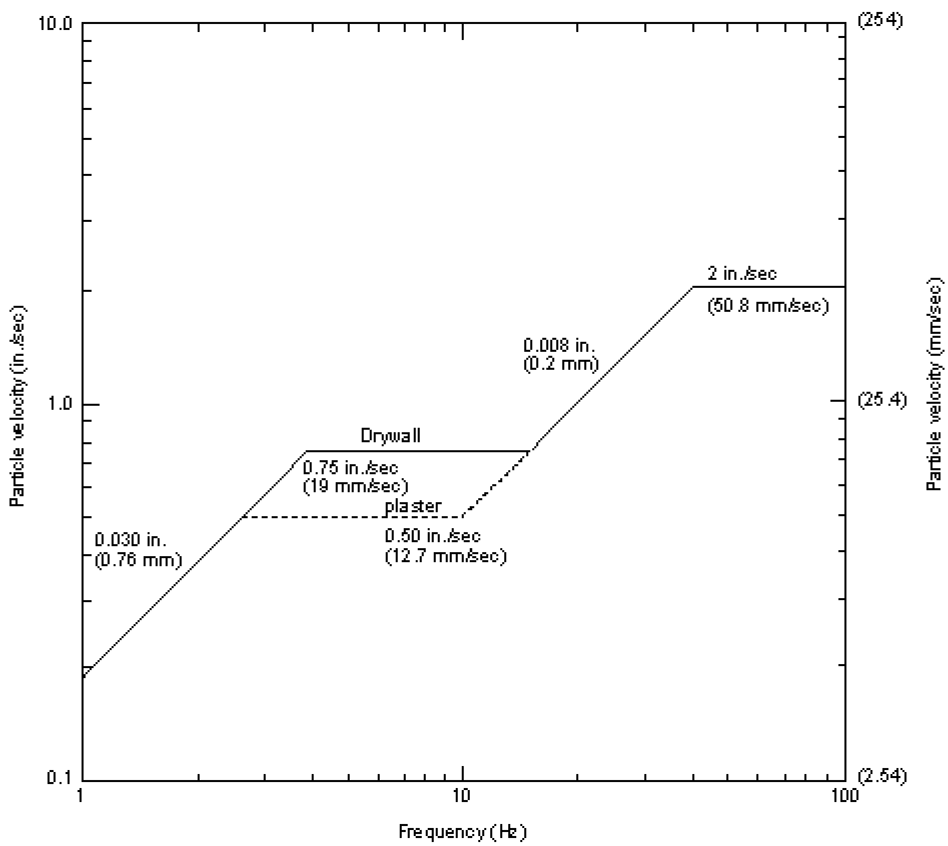


Figure 8-1.2(a) Frequency vs. particle velocity graph.

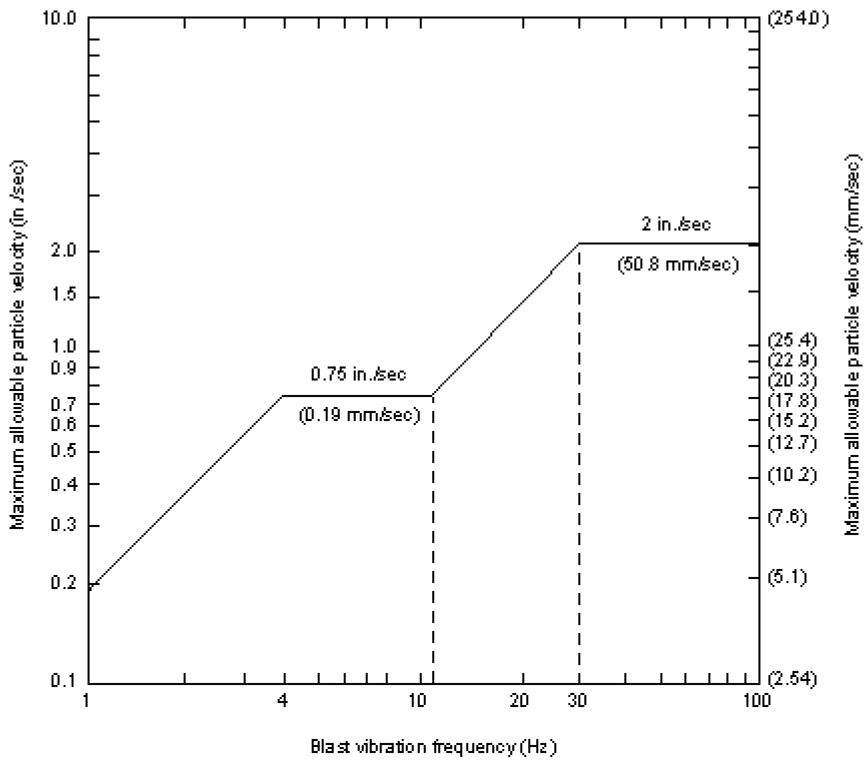


Figure 8-1.2(b) Frequency vs. particle velocity graph.

Table 8-1.3 Scaled Distance Equations

Distance from Blasting Site	Scaled Distance[1] Equation
0 ft to 300 ft (0 m to 91.4 m)	W (lb) = $(D (ft)/50)^2$ [W (kg) = $(D (m)/22.6)^2$]
301 ft to 5000 ft (92 m to 1524 m)	W (lb) = $(D (ft)/55)^2$ [W (kg) = $(D (m)/24.9)^2$]
5001 ft (1525 m) and over	W (lb) = $(D (ft)/65)^2$ [W (kg) = $(D (m)/29.4)^2$]

W = The maximum weight of explosives in pounds (or kilograms) that can be detonated per delay interval of 8 milliseconds or longer.

D = The distance in feet (or meters) from the blast to the nearest dwelling, public building, school, church, or commercial or institutional building not owned, leased, or contracted by the blasting operation, or on property for which the owner has not provided a written waiver to the blasting operation.

[1]To convert English units of scaled distances (ft/lb^2) to metric units (m/kg^2), divide by a factor of 2.21.

8-1.4

Where the blasting operation considers the scaled distance equations of Table 8-1.3 as being too restrictive, the operation shall have the right to petition the authority having jurisdiction to use a modified scaled distance equation. Such a petition shall demonstrate that the use of the modified scaled distance equation would not cause predicted ground vibration that exceeds the peak particle velocity limits specified in Table 8-1.1. Any petition for modification of the scaled distance equations of Table 8-1.3 shall be substantiated thoroughly by seismograph recordings to show that the limitations of Table 8-1.1 cannot be exceeded.

8-2 Airblast.

8-2.1

Airblast at the location of any dwelling, public building, school, church, or commercial or institutional building that is not owned, leased, or contracted by the blasting operation, or on property for which the owner has not provided a written waiver to the blasting operation, shall not exceed the maximum limits specified in Table 8-2.1.

Table 8-2.1 Airblast Limits

Lower Frequency of Measuring System [Hz (± 3 dcb)]	Measurement Level (dcb)
0.1 Hz or lower flat response[1]	134 peak
2 Hz or lower flat response	133 peak
6 Hz or lower flat response	129 peak
C-Weighted slow response[1]	105 peak

[1]Only where approved by the authority having jurisdiction.

8-3 Flyrock.

8-3.1

Flyrock traveling in the air or along the ground shall not be cast from the blast site in an uncontrolled manner that could result in personal injury or property damage.

8-3.2

Flyrock shall not be propelled from the blast site onto property not contracted by the blasting operation or onto property for which the owner has not provided a written waiver to the blasting operation.

8-3.3

Where blasting operations do not conform to 8-3.1 and 8-3.2, the authority having jurisdiction shall require that special precautions be employed to reduce or control flyrock.

Chapter 9 Explosive Materials at Piers and Railway, Truck, and Air Terminals

9-1 Basic Requirements.

9-1.1

Explosive materials shall not be kept in a railway car unless the car, its contents, and methods of loading comply with the regulations of the U.S. Department of Transportation.

Exception: This requirement shall be permitted to be waived in an emergency with the approval of the authority having jurisdiction.

9-1.2

Explosive materials shall not be delivered to any carrier unless the explosives comply in all respects, including marking and packing, to the regulations of the U.S. Department of Transportation.

9-1.3

Every railway car containing explosive materials that has reached its destination, or has stopped in transit so it no longer is considered in interstate commerce, shall remain placarded in accordance with U.S. Department of Transportation regulations.

9-1.4

Any explosive materials at a railway facility, truck terminal, pier, wharf, harbor facility, or airport terminal, whether for delivery to a consignee or forwarded to some other destination, shall be kept in a safe place and isolated as far as practicable and in such a manner that they can be removed easily and quickly.

9-1.5

Truck terminals for explosives vehicles shall meet the requirements of NFPA 498, *Standard for Safe Havens and Interchange Lots for Vehicles Transporting Explosives*.

9-2 Notifications.

A consignee, having been notified that a shipment of explosives is in the hands of any carrier, shall remove the explosives within 48 hours, excluding Saturdays, Sundays, and holidays, to a storage area meeting the requirements of this code.

9-3 Facilities for Trailer-on-Flatcar and Container-on-Flatcar.

Rail shipments of explosives by trailer-on-flatcar (TOFC) or container-on-flatcar (COFC) shall meet the following requirements:

(a) Shipments by TOFC or COFC shall be unloaded at a nonagency station only where a consignee is present to receive them or where properly locked and secure storage facilities are available. If delivery cannot be made, the shipment shall be taken to the next or nearest agency station for delivery.

(b)* Carriers shall require the consignee to remove TOFC and COFC shipments from the carrier's property within 48 hours after notice of arrival, excluding Saturdays, Sundays, and holidays. If the trailers or containers are not so removed, the carrier shall dispose of the shipment immediately by means of storage, disposal, or, where necessary for safety, destruction under the supervision of a competent person.

(c) If storage is required to comply with 9-3.1(b), it shall be located in an interchange lot meeting the requirements of Chapters 2 and 3 of NFPA 498, *Standard for Safe Havens and Interchange Lots for Vehicles Transporting Explosives*, or in a location that provides equivalent safety to the public.

(d) Where local conditions make the acceptance, transportation, or delivery of explosive materials unusually hazardous, appropriate local restrictions shall be imposed by the carrier.

(e) All rail carriers shall report complete information on their restrictions regarding the acceptance, delivery, or transportation of explosive materials over any portion of their lines to the Bureau of Explosives of the Association of American Railroads for publication by the Bureau.

(f) Where shipping explosives, regularly scheduled days for receiving trailers and containers for shipment shall be assigned wherever it is practicable to do so.

(g) To enable the carrier to provide suitable flatcars for the shipment of Division 1.1 or Division 1.2 Explosives, the shipper shall give the carrier at least 24 hours notice of the shipments and their destinations.

Exception: Where a regularly scheduled day has been appointed for receipt of trailers and containers for shipment, this notice shall be permitted to be waived by the carrier. In such cases, the shipments shall be delivered on the assigned days in time to allow proper inspection, billing, and loading on that day.

(h) Carriers shall forward shipments promptly within 48 hours after acceptance at the originating point or after receipt at any yard transfer station or interchange point, excluding Saturdays, Sundays, and holidays.

Exception: Where biweekly or weekly service is provided, shipments shall be forwarded on the next train.

(i) The Bureau of Explosives of the Association of American Railroads shall be consulted by rail carriers to determine that the storage facility required by 9-3.1(b) is safe, adequate, and complies with Chapter 2 of NFPA 498, *Standard for Safe Havens and Interchange Lots for Vehicles Transporting Explosives*.

(j) Cars loaded with explosive materials shall be placed so that they are safe from all probable danger from fire. They shall not be placed under bridges or overhead highway crossings, or in or alongside passenger sheds or stations.

9-4 Designation of Facilities.

The local authority having jurisdiction has the authority to designate the location for, and limit the quantity of, explosive materials that are loaded, unloaded, reloaded, or temporarily retained at any facility within the jurisdiction.

Chapter 10* Plosophoric Materials

10-1 Basic Requirements.

10-1.1

Mixed or combined plosophoric materials shall be transported, stored, and used in the same manner as explosive materials. (*See Chapters 2, 5, 6, and 7*.)

10-1.2

For transportation and storage, individual packages of each plosophoric component shall be packaged in separate shipping containers in compliance with the U.S. Department of Transportation, "Hazardous Materials Regulations," 49 CFR, Parts 100-199.

10-2 Storage.

10-2.1

Plosophoric components shall be stored in separate locked containers. If any component possesses a hazard classification, it shall be stored in a location and manner appropriate to its hazard class.

10-2.2

Plosophoric materials shall be permitted to be stored in the same magazine with explosive materials, provided their total weight is included in the weight of explosives permitted in the magazine in order to comply with the quantity-distance requirements of Table 6-4.1. Storage shall not introduce a hazard due to chemical incompatibility.

10-3 Use.

10-3.1

Where plosophoric materials are mixed or combined at the point of use, the procedures recommended by the manufacturer shall be followed strictly.

10-3.2

Since the mixing or combining of plosophoric components produces an explosive material, the number of packages combined at any one time shall be limited to the number needed for immediate use.

Exception: This requirement shall be permitted to be waived, provided the extra explosive material produced can be handled and stored as such.

10-4 Record Keeping and Reporting.

10-4.1

Dealers in plosophoric materials shall record all transactions on appropriate federal, state, and local forms, as required for transactions with explosive materials.

10-4.2

Thefts of plosophoric materials during transportation, storage, and use shall be reported to the authority having jurisdiction, as required for thefts of explosive materials.

10-4.3

Dealers in plosophoric materials shall require that all purchasers possess a license or permit to use explosive materials. The license or permit number shall be recorded with other records of the sale.

Chapter 11 Small Arms Ammunition and Primers, Smokeless Propellants, and Black Powder Propellants

11-1 Basic Requirements.

11-1.1

In addition to all other applicable requirements of this code, intrastate transportation of small arms ammunition, small arms primers, smokeless propellants, and black powder shall comply with the U.S. Department of Transportation, "Hazardous Materials Regulations," 49 CFR, Parts 100-199.

11-1.2

This chapter shall apply to the users and distribution channels of small arms ammunition, small arms primers, smokeless propellants, and black powder.

11-1.3

This chapter shall not apply to in-process storage and intraplant transportation during manufacture.

11-1.4

This chapter shall apply to the transportation and storage of small arms ammunition and components.

11-1.5

This chapter shall not apply to safety procedures in the use of small arms ammunition and components.

11-2 Small Arms Ammunition.

11-2.1

No restrictions shall be imposed on transportation of small arms ammunition other than those imposed by the U.S. Department of Transportation or by the presence of other hazardous materials.

11-2.2

No quantity limitations shall be imposed on the storage of small arms ammunition in warehouses, retail stores, and other occupancies other than those imposed by the limitations of the storage facility and by public safety regulations.

11-2.3

Small arms ammunition shall be separated from materials classified by the U.S. Department of Transportation as flammable liquids, flammable solids, and oxidizing materials by a distance of 15 ft (4.6 m) or by a fire partition having a fire resistance of at least 1 hour.

11-2.4

Small arms ammunition shall not be stored together with Division 1.1, Division 1.2, or

Division 1.3 Explosives.

Exception: Where the storage facility is suitable for the storage of explosive materials.

11-2.5*

Small arms ammunition that has been exposed to fire or has been damaged by exposure to water shall not be returned to commercial channels for reasons of consumer safety. The manufacturer shall be contacted to obtain recommendations for the disposal of damaged ammunition.

11-3 Smokeless Propellants.

11-3.1

Quantities of smokeless propellants not exceeding 25 lb (11.3 kg) in shipping containers approved by the U.S. Department of Transportation shall be permitted to be transported in a private vehicle.

11-3.2

Quantities of smokeless propellants exceeding 25 lb (11.3 kg), but not exceeding 50 lb (22.7 kg), transported in a private vehicle shall be transported in a portable magazine having wood walls of at least 1-in. (25.4-mm) nominal thickness.

11-3.3

Transportation of more than 50 lb (22.7 kg) of smokeless propellants in a private vehicle shall be prohibited.

11-3.4

Commercial shipments of smokeless propellants in quantities not exceeding 100 lb (45.4 kg) are classified for transportation purposes as flammable solids where packaged in accordance with the U.S. Department of Transportation, "Hazardous Materials Regulations," 49 CFR, Part 173.197, and shall be transported accordingly.

11-3.5

Commercial shipments of smokeless propellants exceeding 100 lb (45.4 kg) or not packaged in accordance with the regulations cited in 11-3.4 shall be transported in accordance with the U.S. Department of Transportation regulations for Class B propellant explosives.

11-3.6

Smokeless propellants shall be stored in shipping containers specified by U.S. Department of Transportation Hazardous Materials Regulations.

11-3.7

Smokeless propellants intended for personal use in quantities not exceeding 20 lb (9.1 kg) shall be permitted to be stored in original containers in residences. Quantities exceeding 20 lb (9.1 kg), but not exceeding 50 lb (22.7 kg), shall be permitted to be stored in residences where kept in a wooden box or cabinet having walls of at least 1 in. (25.4 mm) nominal thickness.

11-3.8

Not more than 20 lb (9.1 kg) of smokeless propellants, in containers of a 1-lb (0.45-kg) maximum capacity, shall be displayed in commercial establishments.

11-3.9

Commercial stocks of smokeless propellants shall be stored as follows:

(a) Quantities exceeding 20 lb (9.1 kg), but not exceeding 100 lb (45.4 kg), shall be stored in portable wooden boxes having walls of at least a 1-in. (25.4-mm) thickness.

(b) Quantities exceeding 100 lb (45.4 kg), but not exceeding 800 lb (363 kg), shall be stored in nonportable storage cabinets having walls of at least a 1-in. (25.4-mm) thickness. Not more than 400 lb (181 kg) shall be permitted to be stored in any one cabinet, and cabinets shall be separated by a distance of an least 25 ft (7.63 m) or by a fire partition having a fire resistance of at least 1 hour.

(c) Quantities exceeding 800 lb (363 kg), but not exceeding 5000 lb (2268 kg), shall be permitted to be stored in a building, provided the following requirements are met:

1. The warehouse or storage room shall not be accessible to unauthorized personnel.

2. Smokeless propellant shall be stored in nonportable storage cabinets having wood walls of at least 1 in. (25.4 mm) thickness and having shelves with no more than 3 ft (0.92 m) of separation between shelves.

3. No more than 400 lb (181 kg) shall be stored in any one cabinet.

4. Cabinets shall be located against the walls of the storage room or warehouse with at least 40 ft (12.2 m) between cabinets.

5. The separation between cabinets shall be permitted to be reduced to 20 ft (6.1 m) where barricades twice the height of the cabinets are attached to the wall, midway between each cabinet. The barricades shall extend at least 10 ft (3 m) outward, shall be firmly attached to the wall, and shall be constructed of $^1/_4$-in. (6.4-mm) boiler plate, 2-in. (51-mm) thick wood, brick, or concrete block.

6. Smokeless propellant shall be separated from materials classified by the U.S. Department of Transportation as flammable liquids, flammable solids, and oxidizing materials by a distance of 25 ft (7.63 m) or by a fire partition having a fire resistance of at least 1 hour.

7. The building shall be protected by an automatic sprinkler system installed in accordance with NFPA 13, *Standard for the Installation of Sprinkler Systems*.

(d) Smokeless propellants not stored in accordance with 11-3.9(a), (b), and (c) shall be stored in a Type 4 magazine constructed and located in accordance with Chapter 6.

11-4 Black Powder.

11-4.1

Black powder shall be transported in accordance with the U.S. Department of Transportation Regulations. (*See also Chapter 5*.)

11-4.2

Black powder shall be stored in shipping containers approved by the U.S. Department of Transportation.

11-4.3

Black powder intended for personal use in quantities not exceeding 20 lb (9.1 kg) shall be permitted to be stored in residences where kept in the original containers and stored in a wooden box or cabinet having walls of at least a 1-in. (25.4-mm) nominal thickness.

11-4.4

No more than 1 lb (0.45 kg) of black powder shall be displayed in commercial establishments.

11-4.5

Commercial stocks stored in buildings in quantities not exceeding 50 lb (22.7 kg) shall be stored in a Type 4 indoor magazine.

11-4.6

Commercial stocks in quantities exceeding 50 lb (22.7 kg) shall be stored in a Type 4 outdoor magazine.

11-4.7

Where smokeless propellants are stored in the same magazine with black powder, the total quantity shall not exceed that permitted for black powder.

11-4.8

Commercial shipments of black powder intended for personal use in small arms shall be permitted to be shipped in quantities not exceeding 50 1b (23 kg), subject to the requirements of the U.S. Department of Transportation, *Exemption Certificate E-8958*.

11-5 Small Arms Primers.

11-5.1

Small arms primers shall be transported or stored in containers approved by the U.S. Department of Transportation.

11-5.2

Transportation of small arms primers shall comply with U.S. Department of Transportation Regulations.

11-5.3

No more than 25,000 small arms primers shall be permitted to be transported in a private vehicle.

11-5.4

No more than 10,000 small arms primers shall be permitted to be stored in residences.

11-5.5

No more than 10,000 small arms primers shall be permitted to be displayed in commercial establishments.

11-5.6

Commercial stocks of small arms primers shall be stored as follows:

(a) Quantities not exceeding 750,000 shall be permitted to be stored in a building where not more than 100,000 are stored in any one pile and where piles are at least 15 ft (4.6 m) apart.

(b) Quantities exceeding 750,000 shall be permitted to be stored in a building, provided the following conditions are met:

1. The warehouse or storage room shall not be accessible to unauthorized personnel.

2. Primers shall be stored in cabinets. No more than 200,000 primers shall be stored in any one cabinet.

3. Shelves in cabinets shall have a vertical separation of at least 2 ft (0.6 m).

4. Cabinets shall be located against the walls of the warehouse or storage room with at least 40 ft (12.2 m) between cabinets.

5. The separation between cabinets shall be permitted to be reduced to 20 ft (6.1 m) where barricades twice the height of the cabinets are attached to the wall, midway between each cabinet. The barricades shall extend at least 10 ft (3 m) outward, shall be firmly attached to the wall, and shall be constructed of $^{1}/_{4}$-in. (6.4-mm) boiler plate, 2-in. (51-mm) thick wood, brick, or concrete block.

6. Primers shall be separated from materials classified by the U.S. Department of Transportation as flammable liquids, flammable solids, and oxidizing materials by a distance of 25 ft (7.63 m) or by a fire partition having a fire resistance of at least 1 hour.

7. The building shall be protected by an automatic sprinkler system installed in accordance with NFPA 13, *Standard for the Installation of Sprinkler Systems*.

(c) Small arms primers not stored in accordance with 11-5.6(a) or (b) shall be stored in a magazine meeting the requirements of Chapter 6.

Chapter 12 Referenced Publications

12-1

The following documents or portions thereof are referenced within this code and shall be considered part of the requirements of this document. The edition indicated for each reference is the current edition as of the date of the NFPA issuance of this document.

12-1.1 NFPA Publications.

National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.

NFPA 10, *Standard for Portable Fire Extinguishers*, 1994 edition.

NFPA 13, *Standard for the Installation of Sprinkler Systems*, 1996 edition.

NFPA 70, *National Electrical Code*, 1996 edition.

NFPA 430, *Code for the Storage of Liquid and Solid Oxidizers*, 1995 edition.

NFPA 498, *Standard for Safe Havens and Interchange Lots for Vehicles Transporting Explosives*, 1996 edition.

NFPA 1122, *Code for Model Rocketry*, 1994 edition.

NFPA 1123, *Code for Fireworks Display*, 1995 edition.

NFPA 1124, *Code for the Manufacture, Transportation, and Storage of Fireworks*, 1995 edition.

NFPA 1125, *Code for the Manufacture of Model Rocket and High Power Rocket Motors*, 1995 edition.

NFPA 1126, *Standard for the Use of Pyrotechnics before a Proximate Audience*, 1996 edition.

NFPA 1127, *Code for High Power Rocketry*, 1995 edition.

12-1.2 Other Publications.

12-1.2.1 IME Publications. Institute of Makers of Explosives, 1120 19th St. NW, Suite 310, Washington, DC 20036-3605.

"American Table of Distances for Storage of Explosives," June 1991.

IME Safety Library Publication No. 20, *Safety Guide for the Prevention of Radio Frequency Radiation Hazards in the Use of Commercial Electric Detonators (Blasting Caps)*, December 1988.

12-1.2.2 U.S. Government Publications. U.S. Government Printing Office, Washington, DC 20402.

Title 18, *United States Code*, "Importation, Manufacture, Distribution and Storage of Explosive Materials," in Chapter 40.

Title 18, *United States Code*, "Organized Crime Control Act of 1970," in Chapter 40.

Title 18, *United States Code*, Chapter 44, "Gun Control Act of 1968."

Title 27, *Code of Federal Regulations*, "Table of Distances for Low Explosives," U.S. Bureau of Alcohol, Tobacco, and Firearms, Part 55.

Title 49, *Code of Federal Regulations*, "Federal Motor Carrier Safety Regulations," U.S. Department of Transportation, Part 397.

Title 49, *Code of Federal Regulations*, "Hazardous Materials Regulations," U.S. Department of Transportation, Parts 100-199.

U.S. Department of Transportation, *Exemption Certificate E-8958*.

Appendix A Explanatory Material

This Appendix is not a part of the requirements of this NFPA document but is included for informational purposes only.

A-1-4 Blasting Agent. Such materials or mixtures have been found to be so insensitive that there is little probability of accidental initiation of explosion or of transition from deflagration to detonation. Blasting agents are 1.5D materials, and tests required to classify these materials are specified in the U.S. Department of Transportation, "Hazardous Materials Regulations," Title 49, *Code of Federal Regulations*, Parts 173.56, 173.57, and 173.58.

A-1-4 Blast Site. The word "barrier" means an object or objects that separates, keeps apart, or demarcates in a conspicuous manner by means of cones, a warning sign, or tape.

A-1-4 Bullet-Resistant Construction. Tests to determine bullet-resistance are to be conducted on test panels or empty magazines. The panels or magazines are to resist penetration of 5 out of 5 shots placed independently of each other in an area at least 3 ft × 3 ft (0.9 m × 0.9 m). If hardwood or softwood is used, its water content is not to exceed 15 percent.

Where a magazine roof or ceiling is required to be bullet-resistant, it shall be constructed of materials comparable to the sidewalls or of other materials that can withstand the penetration of bullets fired at an angle of 45 degrees from perpendicular.

A-1-4 Cap-Sensitive Explosive Material. A No. 8 blasting cap contains 0.40 to 0.45 grams of PETN (pentaerythritol tetranitrate) base charge pressed into an aluminum shell having a bottom thickness not greater than 0.03 in. (0.8 mm) to a specific gravity of not less than 1.4 g/cc and primed with standard weights of primer, in accordance with the manufacturer's specifications.

A-1-4 Explosive. A list of explosives determined to be within the scope of Title 18, *United States Code*, Chapter 40, is published at least annually by the Bureau of Alcohol, Tobacco, and Firearms, U.S. Department of the Treasury.

The classification of explosives described in the "Hazardous Materials Regulations" of the U.S. Department of Transportation is provided in Appendix E. These regulations were revised in 1991.

A-1-4 Flash Point. See also NFPA 30, *Flammable and Combustible Liquids Code*.

A-1-4 Oxidizing Material. See NFPA 430, *Code for the Storage of Liquid and Solid Oxidizers*.

A-1-4 Special Industrial Explosive Material. The high explosives used include dynamite, TNT (trinitrotoluene), PETN (pentaerythritol tetranitrate), and RDX (cyclotrimethylenetrinitramine).

A-1-4 Water Gel. Water gels (or slurries) are manufactured with varying degrees of sensitivity to initiation and are classified as Division 1.1D or 1.5D Explosives, as appropriate. Water gels can be sensitized by a material that itself is classified as an explosive material, such as TNT or smokeless powder, or they might not contain any ingredient classified as an explosive. Water gels in this latter category are sensitized using metals such as aluminum or using other fuels.

A-2-8.5 The toll-free telephone number for reporting incidents to the Bureau of Alcohol, Tobacco, and Firearms is 800-800-3855.

A-3-4.2 See NFPA 490, *Code for the Storage of Ammonium Nitrate*, for guidance in choosing compatible materials.

A-6-6.1(c) A bullet-resistant roof may be permitted to be constructed in accordance with any of the specifications in Appendix C. A bullet-resistant ceiling may be permitted to be constructed at the eave line, covering the entire area of the magazine, excluding the necessary ventilation space. Examples of bullet-resistant ceiling construction include:

(a) Any construction meeting the specifications in Appendix C.

(b) A sand tray having a sand depth of at least 4 in. (102 mm).

A-7-1.16(b) For further information, see IME Safety Library Publication No. 20, *Safety Guide for the Prevention of Radio Frequency Radiation Hazards in the Use of Commercial Electric Detonators (Blasting Caps)*.

A-7-6.4 The member companies of the Institute of Makers of Explosives have agreed to supply advice on or assistance in destroying commercial explosives to law enforcement agencies, fire departments, and inspection and regulatory officials, as well as to users of explosives. The manufacturer, if known, should be consulted for assistance. If the manufacturer is not known, a member company of the Institute of Makers of Explosives can provide advice or assistance.

A-9-3(b) The specific requirement is provided in the U.S. Department of Transportation, "Hazardous Materials Regulations," 49 CFR, Part 174.16.

A-10 Plosophoric materials, or plosophors, also are known as two-component or binary explosives.

A-11-2.5 A bulletin on this subject is available from the Sporting Arms and Ammunition Manufacturer’s Institute, Inc., Flintlock Ridge Office Center, 11 Mile Hill Road, Newtown, CT 06470-2359.

Appendix B Recommended Separation Distances of Ammonium Nitrate and Blasting Agents from Explosives or Blasting Agents

This Appendix is not a part of the requirements of this NFPA document but is included for informational purposes only.

B-1 Derivation of Table.

B-1.1 The Table of Recommended Separation Distances of Ammonium Nitrate and Blasting Agents from Explosives or Blasting Agents is shown in Table 6-4.2.

B-1.2 A test program sponsored by the Chemical Manufacturers Association and the Institute of Makers of Explosives and conducted by the U.S. Bureau of Mines developed data on the relative sensitivity of ammonium nitrate (AN) and ammonium nitrate/fuel oil (ANFO) to sympathetic detonation. The data then was applied to the American Table of Distances for Storage of Explosives (*see Table 6-4.1*) to produce the table of recommended separation distances for ammonium nitrate and blasting agents from stores of high explosives or other blasting agents.

B-1.3 The American Table of Distances for barricaded storage of explosives has proven adequate through the years; no data developed in this test program suggested the need for modification of the table. However, a factor of 2 has been suggested in the past for increasing the distances from unbarricaded magazines. The results, employing two charge sizes of AN and one of ANFO, yielded ratios of unbarricaded to barricaded distances of 4.2 to 7.4. This averaged to a factor of approximately 6, which was taken to be appropriate. Therefore, unbarricaded stores of AN or ANFO not in bullet-resistant magazines should have six times the separation distances of barricaded stores.

B-1.4 The relative sensitivity of AN and ANFO to dynamite was obtained by examining the relative K factors for 50 percent propagation distances where the cube root of the weight was employed in the following equation:

$$S = KW^{1/3}$$

where:

S = distance in ft

W = weight in lb

This equation allowed the comparison of 1600-lb (726.4-kg) dynamite acceptors with 5400-lb (2451.6-kg) AN and ANFO acceptors; the results of these large charges are believed to be the most reliable available. The ratio of K factors for dynamite and AN was 6.27, which was rounded to 6. The ratio for dynamite and ANFO was 1.6. These factors were applied to the American Table of Distances, thereby reducing the distance for barricaded AN to $^{1}/_{6}$ the corresponding distance for explosives. The corresponding reduction for ANFO was 0.6.

B-1.5 One point should be emphasized: the distances in the table are for the separation of stores only. Since the blast effect from ANFO is not significantly less than from high explosives, the American Table of Distances still should be used for separation from inhabited buildings, passenger railways, and public highways. (The blast effect from AN is about 50 percent of that from high explosives.) Further, the blast effect is not modified significantly by barricades. The American Table of Distances for unbarricaded stores provides an additional factor of safety and should be used.

B-2 Guide to Use of the Table.

B-2.1 A sketch of the location of all potential donor and acceptor materials together with the maximum mass of material to be permitted in that vicinity should be made. (Potential donors are high explosives, blasting agents, and combinations of masses of detonating materials. Potential acceptors are high explosives, blasting agents, and ammonium nitrate.)

B-2.2 Each donor mass should be considered separately in combination with each acceptor mass. If the masses are closer than the table allowance (distances measured between the nearest edges), the combination of masses becomes a new potential donor of weight equal to the total mass. Where individual masses are considered as donors, the distances to potential acceptors should be measured between the edges. Where combined masses within propagating distance of each other are considered as a donor, the appropriate distance to the edge of potential acceptors should be computed as a weighted distance from the combined masses.

The calculation of the weighted distance from combined masses is as follows:

M_2, M_3.. M_n are donor masses to be combined.

M_1 is a potential acceptor mass.

D_{12} is the distance from M_1 to M_2 (edge to edge).

D_{13} is the distance from M_1 to M_3 (edge to edge), etc.

To find the weighted distance [$D_1(_{2,3} \ldots\ldots\ldots\ldots _n)$] from combined masses to M_1, the products of the individual masses and distances are added and the total is divided by the sum of the masses, as follows:

$$D_1(_{2,3}, \ldots\ldots\ldots\ldots _n) = \frac{M_2 \times D_{12} + M_3 \times D_{13} \ldots M_n \times D_{1n}}{M_2 + M_3 \ldots M_n}$$

Propagation is possible where either an individual donor mass is located at less than the tabulated distance from an acceptor or a combined mass is located at less than the weighted distance from an acceptor.

B-2.3 In determining the distances separating highways, railroads, and inhabited buildings from potential explosions (*see Table 6-4.1*), the sum of all masses that can propagate (i.e., lie at distances less than those prescribed in the table) from either individual or combined donor masses is included. However, where the ammonium nitrate is to be included, only 50 percent of its weight shall be used because of its reduced blast effects.

In applying the American Table of Distances to distances from highways, railroads, and inhabited buildings, distances are measured from the nearest edge of potentially explodable material as prescribed in the American Table of Distances, Note 5. (*See Table 6-4.1.*)

B-2.4 When all or part of a potential acceptor comprise Division 1.1 and Division 1.2 Explosives, as defined in DOT regulations, storage in bullet-resistant magazines is required. Safe distances to stores in bullet-resistant magazines can be obtained from the intermagazine distances prescribed in the American Table of Distances.

B-2.5 Barricades are not to have line-of-sight openings between potential donors and acceptors that allow blast or missiles to move directly between masses. [*See Tables B-2.5(a) and (b)*].

Table B-2.5(a)

Example 1	**ANFO Mix Plant (*see* *Figure B-2.5*)**
M_1	100,000 lb Fertilizer AN prills (maximum)
M_2	2500 lb ANFO (maximum)
M_3	80,000 lb ANFO (maximum)
D_{12}	20 ft
D_{23}	20 ft
D_{13}	50 ft

Note: No other stores on site; no barricade exists.
(For SI Units: 1 lb = 0.454 kg; 1 ft = 0.305 m)

Potential Donor	Potential Acceptor	Distance on Site (ft)	Table Distance, Minimum Required (ft)	Propagation Possible?
M_2 (2500 lb)	M_1	20	9 × 6 = 54	Yes
M_2 (2500 lb)	M_3	20	32 × 6 = 192	Yes
M_3 (80,000 lb)	M_1	50	28 × 6 = 168	Yes

M_3 (80,000 lb)	M_2	20	101 × 6 = 606	Yes

Conclusion:

The maximum amount of blasting agent to be considered for public protection at this site is the sum of all masses, reducing Fertilizer AN mass by 50 percent as indicated in B-2.3.

100,000 × 50% =	50,000
	2500
	80,000
	132,500 lb

In accordance with the American Table of Distances, the required separation distance from an inhabited building (unbarricaded) is 2000 ft.

Table B-2.5(b)

Example 2	**ANFO Mix Plant (*see* *Figure B-2.5*)**
M_1	100,000 lb Fertilizer AN prills (maximum)
M_2	2500 lb ANFO (maximum)
M_3	80,000 lb ANFO (maximum)
D_{12}	20 ft
D_{23}	20 ft
D_{13}	50 ft

Note: No other stores on site; a 4-ft (1.2-m) thick earth barricade exists at B (*see Figure B-2.5*).
(For SI Units: 1 lb = 0.454 kg; 1 ft = 0.305 m)

Potential Donor	**Potential Acceptor**	**Distance on Site (ft)**	**Table Distance, Minimum Required (ft)**	**Propagation Possible?**
M_2(2500 lb)	M_1	20	9	No
M_2(2500 lb)	M_3	20	6 × 32 = 192	Yes
M_3(80,000 lb)	M_1	50	28	No

M_3(80,000 lb)	M_2	20	6 × 101 = 606	Yes
Combined $M_2 + M_3$ (82,500 lb)	M_1	49[1]	30	No

[1]Compute weighted distance to combined mass by equation 1:

$$\frac{2500 \times 20 + 80{,}000 \times 50}{2500 + 80{,}000} = 49 \text{ ft}$$

Conclusion:

The maximum amount of blasting agent to be considered for public protection at this site is the sum of M_2 plus M_3, or 82,500 lb (37,455 kg). In accordance with the American Table of Distances, the required separation distance from an inhabited building (unbarricaded) is 2000 ft (610 m). Where a natural or artificial barricade protects the building, the required distance is 1730 ft (528 m).

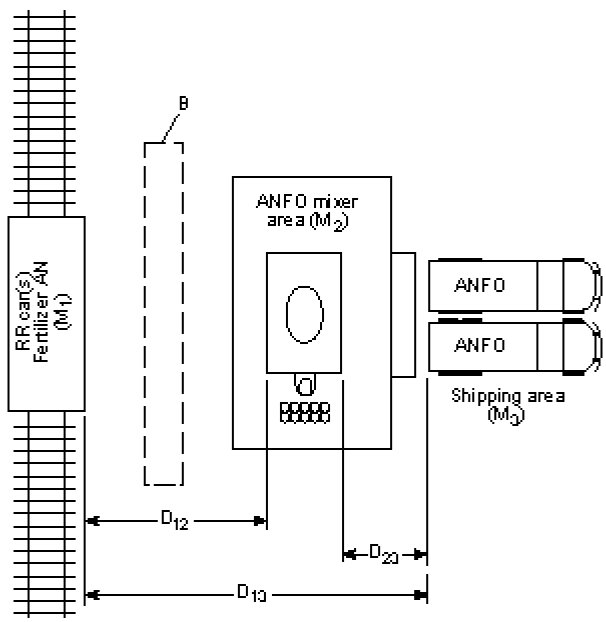


Figure B-2.5 ANFO mix plant.

Appendix C Magazine Construction

This Appendix is not a part of the requirements of this NFPA document but is included for informational purposes only.

Magazines constructed in accordance with the following minimum specifications are approved as bullet-resistant (as defined in Chapter 1). All steel and wood dimensions are actual thickness; concrete block and brick dimensions are nominal.

C-1 Steel Exterior.

C-1.1 $^5/_8$-in. (15.9-mm) steel with an interior lining of nonsparking material.

C-1.2 $^1/_2$-in. (12.7-mm) steel with an interior lining of plywood at least $^3/_8$ in. (9.5 mm) thick.

C-1.3 $^3/_8$-in. (9.5-mm) steel lined with one of the following:

(a) 2 in. (50.8 mm) of hardwood;

(b) 3 in. (76.2 mm) of softwood;

(c) $2^1/_4$ in. (57.1 mm) of plywood.

C-1.4 $^1/_4$-in. (6.3-mm) steel lined with one of the following:

(a) 3 in. (76.2 mm) of hardwood;

(b) 5 in. (127 mm) of softwood;

(c) $5^1/_4$ in. (133.3 mm) of plywood;

(d) $1^1/_2$ in. (38.1 mm) of plywood with an intermediate layer of 2 in. (50.8 mm) of hardwood.

C-1.5 $^3/_{16}$-in. (4.8-mm) steel lined with one of the following:

(a) 4 in. (101.6 mm) of hardwood;

(b) 7 in. (177.8 mm) of softwood;

(c) $6^3/_4$ in. (171.5 mm) of plywood;

(d) $^3/_4$ in. (19 mm) of plywood with an intermediate layer of 3 in. (76.2 mm) of hardwood.

C-1.6 $^1/_8$-in. (3.2-mm) steel lined with one of the following:

(a) 5 in. (127 mm) of hardwood;

(b) 9 in. (228.6 mm) of softwood;

(c) $^3/_4$ in. (19 mm) of plywood with an intermediate layer of 4 in. (101.6 mm) of hardwood.

(d) Two layers of $^3/_4$-in. (19-mm) plywood with an intermediate layer of $3^5/_8$ in. (92.1 mm) of well-tamped dry sand or sand/cement mixture.

C-2 Fire-Resistant Exterior. The exterior of any type of fire-resistant material that is structurally sound may be permitted to be constructed with the following:

(a) An interior lining of $^1/_2$-in. (12.7-mm) plywood placed securely against an intermediate 4-in. (101.6-mm) thick layer of solid concrete block, solid brick, or solid concrete.

(b) An interior lining of $^3/_4$-in. (19-mm) plywood; a first intermediate layer of $^3/_4$-in. (19-mm) plywood; a second intermediate layer of $3^5/_8$ in. (92.1 mm) of well-tamped dry sand or sand/cement mixture; a third intermediate layer of $^3/_4$-in. (19-mm) plywood; and a fourth intermediate layer of 2-in. (50.8-mm) hardwood or 14-gauge steel.

(c) An intermediate 6-in. (152.4-mm) space filled with well-tamped dry sand or sand/cement mixture.

C-3 Masonry Exterior.

C-3.1 Standard 8-in. (203.2-mm) concrete block with voids filled with well-tamped dry sand or sand/cement mixture.

C-3.2 Standard 8-in. (203.2-mm) solid brick.

C-3.3 8-in. (203.2-mm) solid concrete.

C-3.4 Two layers of 4-in. (101.6-mm) concrete block.

Appendix D Training and Information Sources

This Appendix is not a part of the requirements of this NFPA document but is included for informational purposes only.

D-1 General. This appendix summarizes available training and educational material that provides useful supplementary information regarding explosives.

D-2 IME Educational Materials. Institute of Makers of Explosives, 1120 Nineteenth St. NW, Suite 310, Washington, DC 20036-3605.

D-2.1 Videos.

"Don't Touch," pertaining to blasting cap safety.

"Emergency Instructions," pertaining to first response for transportation accidents involving explosives.

"Storage of Commercial Explosive Material."

D-2.2 Posters. Assorted posters pertaining to blasting cap safety, emergency responses, and other important safety issues.

D-2.3 Publications.

Safety Library Publication No. 1, "Construction Guide for Storage Magazines," June 1986.

Safety Library Publication No. 2, "The American Table of Distances," June 1991.

Safety Library Publication No. 3, "Suggested Code of Regulations for the Manufacture, Transportation, Storage, Sale, Possession, and Use of Explosive Materials," January 1985.

Safety Library Publication No. 4, "Warnings and Instructions for Consumers in Transporting, Storing, Handling and Using Explosive Materials," June 1989.

Safety Library Publication No. 12, "Glossary of Commercial Explosives Industry Terms," February 1991.

Safety Library Publication No. 14, "Handbook for the Transportation and Distribution of Explosive Materials," June 1986.

Safety Library Publication No. 17, "Safety in the Transportation, Storage, Handling, and Use of Explosive Materials," March 1987.

Safety Library Publication No. 20, "Safety Guide for the Prevention of Radio Frequency Radiation Hazards in the Use of Commercial Electric Detonators (Blasting Caps)," December 1988.

Safety Library Publication No. 21, "Destruction of Commercial Explosive Materials," September 1987.

Safety Library Publication No. 22, "Recommendations for the Safe Transportation of Detonators in a Vehicle with Certain Other Explosive Materials," January 1, 1985.

"Guide for the Use of IME 22 Container," July 1991.

D-3 SAAMI Educational Materials. Sporting Arms and Ammunition Manufacturers' Institute, Inc., 555 Danbury Rd., Wilton, CT 06897.

D-3.1 Video.

"Sporting Ammunition and the Firefighter."

D-4 Miscellaneous Reference Materials.

Atlas Powder Co. (Dallas, TX). *Handbook of Electric Blasting*, Rev. 1985, 74 pp.

Borg, D. G., R. F. Chiappetta, R. C. Morhard, and V. A. Sterner. *Explosives and Rock Blasting*. Atlas Powder Co. (Dallas, TX) ISBN 0-9616284-0-5, 1987, 662 pp.

D'Andrea, D. V., and L. R. Fletcher. "Analysis of Recent Mine Blasting Accidents." Paper in Proceedings of the 9th Conference on Explosives and Blasting Technique, C. J. Konya, ed. (Dallas, TX, Jan. 31 Feb. 4, 1983). Soc. Explos. Eng., Montville, OH, 1983, pp. 105-122.

E. I. du Pont de Nemours & Co., Inc. (Wilmington, DE). *Blaster's Handbook*, 16th ed., 1978, 494 pp.

Fischer, R. L. *Blasting Incidents in Mining*. MSHA Program Circular 7026, August 1988, 54 pp.

Appendix E U.S. Department of Transportation Proposed Revisions of Explosive Materials Transport Regulations

This Appendix is not a part of the requirements of this NFPA document but is included for informational purposes only.

E-1 General. On December 21, 1990, the U.S. Department of Transportation (U.S. DOT) issued a final rule that revised the "Hazardous Materials Regulations" contained in Title 49, *Code of Federal Regulations*, Part 173.57.

These regulations cover the classification, packaging, and shipping of explosives (including blasting agents), oxidizers (ammonium nitrate), flammable liquids, and flammable solids.

Essentially, the U.S. DOT revised the U.S. hazardous materials regulations so that they conform to international regulations, which are based on the *United Nations Recommendations on the Transport of Dangerous Goods.* The revised regulations standardize testing and classification procedures, nomenclature, packaging, labeling, placarding, and handling and eliminate inconsistencies that formerly existed between the U.S. (domestic) and UN (international) standards.

It is likely that the most important change for the user of explosive materials is the elimination of the Class A, B, and C Explosives and Blasting Agents. Under the UN recommendations, all explosive materials are placed under Class 1 Explosives. Class 1 is made up of six divisions that represent the characteristics of the properties and hazards of a particular explosive. The breakdown of Class 1 Explosives into its six divisions is provided in Section E-2.

E-2 Class 1 Explosives.

Division 1.1. Explosives that present a mass explosion hazard.

Division 1.2. Explosives that present a projection hazard but not a mass explosion hazard.

Division 1.3. Explosives that present a fire hazard and either a minor blast hazard or a minor projection hazard, or both, but not a mass explosion hazard.

Division 1.4. Explosive devices that present a minor explosion hazard; no device shall contain more than 25 g (0.9 oz) of a detonating material.

Division 1.5. Very insensitive explosives that present a mass explosion hazard but are so insensitive that there is little probability of initiation or of transition from burning to detonation under normal conditions of transport.

Division 1.6. Extremely insensitive articles that do not have a mass explosion hazard, and articles that demonstrate a negligible probability of accidental initiation or propagation [no applicable hazard class].

The classification code for an explosive consists of the division number followed by the compatibility group letter. Compatibility group letters are used to specify the controls for the transportation and related storage of explosives and to prevent an increase in hazard that might result if certain types of explosives are stored or transported together.

Compatibility groups and classification codes for the various types of explosives are provided in the following tables.

Table E-1 provides compatibility groups and classification codes for substances and articles described in the first column.

Table E-1 also provides the number of classification codes that are possible within each explosive division.

Altogether, there are 35 possible classification codes for explosives.

Table E-2 provides explosives compatibility groups that may be transported on the same vehicle.

For comparative purposes, the classification of explosive materials under the UN recommendations and the former U.S. DOT system is provided in Section E-3.

E-3 UN Classification/Former DOT System.

Division 1.1 Class A Explosives. Dynamite, cast boosters, cap sensitive emulsions, water gels and slurries, Class A detonators.

Division 1.2 Class A or Class B Explosives. Division 1.2 generally contains ammunition or materials that present a projection hazard.

Division 1.3 Class B Explosives. Generally propellants or explosives that present a fire hazard but not a mass detonation hazard.

Division 1.4 Class C Explosives. Class C detonators, safety fuse, and other Class C explosives.

Division 1.5 Blasting Agent. ANFO, noncap-sensitive emulsions, water gels, slurries, and packaged blasting agents.

Division 1.6 No Applicable Class. Currently there are no commercial explosives contained in Division 1.6.

In the UN system, oxidizers and organic peroxides form Class 5 Explosives. Ammonium nitrate, an oxidizer, is classified as 5.1 (Class 5, Division 1). Flammable and combustible liquids (fuel oils) are Class 3, and flammable solids are Class 4.

To determine the proper classification of an explosive (class and division) criteria and test procedures have been set up in the UN recommendations. Through these criteria and tests it can be determined initially whether the material is an explosive and, if so, the hazard division to which it belongs.

In addition to the class and division number, every explosive under the UN recommendations has a proper shipping name and a four-digit identification number. Shipping cases are required to show the proper shipping name and the identification number.

Table E-1 Classification Codes

Description of Substances or Article to be Classified	Compatibility Group	Classification Code
Primary explosive substance	A	1.1A
Article containing a primary explosive substance and not containing two or more effective protective features	B	1.1B 1.2B 1.4B
Propellant explosive substance or other deflagrating explosive substance or article containing such explosive substance	C	1.1C 1.2C 1.3C 1.4C
Secondary detonating explosive substance or black powder or article containing a secondary detonating explosive substance, in each case without means of initiation and without a propelling charge; or article containing a primary explosive substance and containing two or more effective protective features	D	1.1D 1.2D 1.4D 1.5D
Article containing a secondary detonating explosive substance, without means of initiation, with a propelling charge (other than one containing flammable liquid or hypergolic liquid)	E	1.1E 1.2E 1.4E
Article containing a secondary detonating explosive substance, with its means of initiation, with a propelling charge (other than one containing flammable liquid or hypergolic liquid) or without a propelling charge	F	1.1F 1.2F 1.3F 1.4F
Pyrotechnic substance or article containing a pyrotechnic substance, or article containing both an explosive substance and an illuminating, incendiary, tear-producing, or smoke-producing substance (other than a water-activated article or one containing white phosphorus, phosphide or flammable liquid or gel or hypergolic liquid)	G	1.1G 1.2G 1.3G 1.4G
Article containing both an explosive substance and white phosphorus	H	1.2H

		1.3H
Article containing both an explosive substance and flammable liquid or gel	J	1.1J 1.2J 1.3J
Article containing both an explosive substance and a toxic chemical agent	K	1.2K 1.3K
Explosive substance or article containing an explosive substance and presenting a special risk (e.g., due to water activation or presence of hypergolic liquids, phosphides, or pyrophoric substances) needing isolation of each type	L	1.1L 1.2L 1.3L
Articles containing only extremely insensitive detonating substances	N	1.6N
Substance or article packed or designed so that any hazardous effects arising from accidental functioning are limited to the extent that they do not significantly hinder or prohibit fire fighting or other emergency response efforts in the immediate vicinity of the package	S	1.4S

Table E-2 Class 1 (Explosives) Compatibility Groups That May Be Transported on the Same Vehicle.[1]

Compatibility Group	A	B	C	D	E	G	S
A	Yes	No	No	No	No	No	No
B	No	Yes	No*	No*	No*	No	Yes
C	No	No*	Yes	Yes	Yes	No	Yes
D	No	No*	Yes	Yes	Yes	No	Yes
E	No	No*	Yes	Yes	Yes	No	Yes
G	No	No	No	No	No	No	Yes
S	No	Yes	Yes	Yes	Yes	Yes	Yes

Footnotes:

*Detonators 1.4B and 1.4S (Explosive C) and certain detonators 1.4B (Explosive A) that contain no more than one (1) gram of explosives (excluding ignition and delay charges) and are electric detonators (electric blasting caps) with leg wires four (4) ft or longer, or detonators (blasting caps) with empty plastic tubing twelve (12) ft or longer shall be transported on the same vehicle with other Class 1 materials (explosives) of Compatibility Groups B, C, D, E, G, or S, provided the detonators are shipped in accordance with IME-22 specifications.

1 NO detonators shall be transported on the same vehicle with Class 1 materials (explosives) Compatibility Groups C, D, E, and G unless the detonators are shipped in accordance with IME-22 specifications.

Under NO circumstances shall detonators of any compatibility group be shipped with Class 1, Compatibility Group A materials that were previously classified as initiating explosives.

Appendix F Referenced Publications

F-1 The following documents or portions thereof are referenced within this code for informational purposes only and thus are not considered part of the requirements of this document. The edition indicated for each reference is the current edition as of the date of the NFPA issuance of this document.

F-1.1 NFPA Publications. National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.

NFPA 30, *Flammable and Combustible Liquids Code*, 1996 edition.

NFPA 430, *Code for the Storage of Liquid and Solid Oxidizers*, 1995 edition.

NFPA 490, *Code for the Storage of Ammonium Nitrate*, 1993 edition.

F-1.2 Other Publications.

F-1.2.1 ANSI Publication. American National Standards Institute, Inc., 1450 Broadway, New York, NY 10018.

ANSI A10.7, "Safety Requirement for the Transportation, Storage, Handling, and Use of Commercial Explosives and Blasting Agents in the Construction Industry," 1970.

F-1.2.2 IME Publications. Institute of Makers of Explosives, 1120 Nineteenth St., NW, Suite 310, Washington, DC 20036-3605.

Safety Library Publication No. 1, "Construction Guide for Storage Magazines," June 1986.

Safety Library Publication No. 2, "The American Table of Distances," June 1991.

Safety Library Publication No. 3, "Suggested Code of Regulations for the Manufacture, Transportation, Storage, Sale, Possession, and Use of Explosive Materials," January 1985.

Safety Library Publication No. 4, "Warnings and Instructions for Consumers in Transporting, Storing, Handling, and Using Explosive Materials," June 1989.

Safety Library Publication No. 12, "Glossary of Commercial Explosives Industry Terms," February 1991.

Safety Library Publication No. 14, "Handbook for the Transportation and Distribution of Explosive Materials," June 1986.

Safety Library Publication No. 17, "Safety in the Transportation, Storage, Handling, and Use of Explosive Materials," March 1987.

Safety Library Publication No. 20, "Safety Guide for the Prevention of Radio Frequency Radiation Hazards in the Use of Commercial Electric Detonators (Blasting Caps)," December 1988.

Safety Library Publication No. 21, "Destruction of Commercial Explosive Materials," September 1987.

Safety Library Publication No. 22, "Recommendations for the Safe Transportation of Detonators in a Vehicle with Certain Other Explosive Materials," January 1, 1985.

"Guide for the Use of IME 22 Container," July 1991.

F-1.2.3 U.S. Government Publications. U.S. Government Printing Office, Washington, DC 20402.

"Ammunition and Explosives Safety Standards," DOD 6055.9-STD, U.S. Department of Defense Explosives Safety Board, Washington, DC 20314.

"ATF: Explosives Laws and Regulations"; ATF Publication 5400,7; U.S. Bureau of Alcohol, Tobacco, and Firearms; Washington, DC; November 1982.

"Explosives and Blasting Procedures Manual"; Dick, R.A., Fletcher, L.R., and D'Andrea, D.V.; Information Circular 8925, U.S. Bureau of Mines, Washington, DC; 1983.

"Explosive Hazard Classification Procedures"; DLAR 8220.1; Defense Logistics Agency, Washington, DC; 1981.

Title 27, *Code of Federal Regulations*, "Explosive Materials Regulations," U.S. Bureau of Alcohol, Tobacco, and Firearms, Parts 55 and 181.

Title 49, *Code of Federal Regulations*, "Hazardous Materials Regulations," U.S. Department of Transportation, Part 174.16.

F-1.2.4 Additional References.

American Civil Engineering Practice, Abbott, Vol. 1, 1956, J. Wiley & Sons, New York, NY.

Definition and Test Procedures for Ammonium Nitrate Fertilizer, 1964, The Fertilizer Institute, 1015 18th St. NW, Washington, DC 20036.

NFPA 496

1993 Edition

Standard for Purged and Pressurized Enclosures for Electrical Equipment

1993 Edition

This edition of NFPA 496, *Standard for Purged and Pressurized Enclosures for Electrical Equipment*, was prepared by the Technical Committee on Electrical Equipment in Chemical Atmospheres and acted on by the National Fire Protection Association, Inc. at its Fall Meeting held November 16-18, 1992 in Dallas, TX. It was issued by the Standards Council on January 15, 1993, with an effective date of February 12, 1993, and supersedes all previous editions.

The 1993 edition of this document has been approved by the American National Standards Institute.

Origin and Development of NFPA 496

This standard was developed in two parts by the Technical Committee on Electrical Equipment in Chemical Atmospheres. The first part, addressing purged enclosures for electrical equipment in Class I Hazardous (Classified) Locations, was adopted as a tentative standard at the 1966 NFPA Annual Meeting and as an official standard at the 1967 NFPA Annual Meeting. The second part, addressing pressurized enclosures for electrical equipment in Class II Hazardous (Classified) Locations, was tentatively adopted at the 1970 NFPA Annual Meeting and officially adopted at the 1971 NFPA Annual Meeting.

The Technical Committee on Electrical Equipment in Chemical Atmospheres presented a complete revision of the entire standard in 1974. In 1980, the Committee began another complete revision. This work culminated in the 1982 edition.

In 1983, the Technical Committee on Electrical Equipment in Chemical Atmospheres recognized the need for specific requirements applicable to process control analyzers that have internal sources of a flammable or combustible material, such as a direct connection to the process stream. Two chapters were added to address analyzer enclosures and analyzer rooms or buildings. Additional changes were also made to certain existing portions of the text specifically to address problems in interpretation of the existing test. The 1986 edition of NFPA 496 is the result of this effort.

In 1987, the Technical Committee on Electrical Equipment in Chemical Atmospheres recognized a need for editorial revisions to the drawings in Chapter 2 as well as some minor editorial changes in Chapters 2 and 9 and the Appendix. The 1989 edition is the result of this effort.

Beginning in 1990, an adhoc committee consisting of members of the Electrical Equipment in Chemical Atmospheres Committee started a major rewrite of this document to develop a more comprehensive standard and to reduce redundancy in the text. Definitions were added for further clarity, and references to Class III were deleted since the standard did not cover this application and could create some confusion. References to purging were replaced with “pressurizing,” and “protective gas” was introduced as a new term. The requirements based on gross internal volume were deleted and replaced with general and specific requirements for all pressurized enclosures used in Class I and Class II locations. The result of this rewrite is the 1993 edition.

The NFPA Technical Committee on Electrical Equipment in Chemical Atmospheres wishes to gratefully acknowledge the efforts of the Instrument Society of America, through its Committee SP12, in the development of the basic requirements for purged and pressurized enclosures. These efforts resulted in the publishing of ISA S12.4, “Instrument Purging for Reduction of Hazardous

Area Classification." ISA S12.4 was the basis for NFPA 496.

Technical Committee on Electrical Equipment in Chemical Atmospheres

R. F. Schwab, *Chairman*
AlliedSignal Inc., NJ

Mark C. Ode, *Secretary*
National Fire Protection Assn., MA
(Nonvoting)

Alonza W. Ballard, Crouse-Hinds ECM, NY
Rep. Nat'l Electrical Mfrs Assn.

Albert A. Bartkus, Underwriters Laboratories Inc., IL

Michael K. Baucom, BEBCO Industries, Inc., TX

Carol M. Boring, U.S. Dept. of Labor, WV

David H. Byford, Unocal Corp., CA
Rep. American Petroleum Inst.

William G. Lawrence, Factory Mutual Research Corp., MA

Richard Y. LeVine, Stamford, CT

Ernest C. Magison, Honeywell Inc., PA
Rep. Instrument Society of America

Richard C. Masek, Bailey Controls, OH

Robert E. McKenney, City of Tacoma, WA

Richard E. Munson, E I du Pont de Nemours & Co., DE

Charles R. Prasso, Industrial Risk Insurers, CT

Milton H. Ramsey, Chevron USA Inc., TX
Rep. Inst. of Electrical & Electronics Engineers, Inc.

John E. Rogerson, Cedar Lane Farm, OH

George H. St Onge, Bernardsville, NJ

James G. Stallcup, Grayboy Publishing Co., TX

Committee Scope: (1) To develop data on the properties of chemicals enabling proper selection of electrical equipment for use in atmospheres containing flammable gases, vapors, or dusts; (2) to make recommendations for the prevention of fires and explosions through the use of intrinsically safe, continuously purged, pressurized, explosion-proof, or dust-ignition-proof electrical equipment when installed in such chemical atmospheres.

NFPA 496
Standard for
Purged and Pressurized Enclosures for Electrical Equipment

1993 Edition

NOTICE: An asterisk (*) following the number or letter designating a paragraph indicates explanatory material on that paragraph in Appendix A.
Information on referenced publications can be found in Chapter 8 and Appendix B.

Chapter 1 General

1-1* Scope.

This standard shall apply to purging and pressurizing:

(a) Electrical equipment located in areas classified as hazardous by Article 500 of NFPA 70, *National Electrical Code*,® and

(b) Electrical equipment containing sources of flammable vapors or gases and located in either classified or nonclassified areas, and

(c) Control rooms or buildings located in areas classified as hazardous by Article 500 of NFPA 70, and

(d) Analyzer rooms containing sources of flammable vapors or gases and located in areas classified as hazardous by Article 500 of NFPA 70, *National Electrical Code*.

1-2 Purpose.

This standard is intended to provide information on the methods for purging and pressurizing enclosures to prevent ignition of a flammable atmosphere. Such an atmosphere may be introduced into the enclosure by a surrounding external atmosphere or by an internal source. By these means, electrical equipment that is not otherwise acceptable for a flammable atmosphere may be utilized in accordance with Article 500 of NFPA 70, *National Electrical Code*.

1-3 Applicability.

1-3.1

Chapters 2, 3, and 4 of this standard shall apply to electrical instrument and process control equipment, motors, motor controllers, electrical switchgear, and similar equipment that are installed in Class I or Class II locations and that <u>do not contain an internal source</u> of flammable vapor, gas, or liquid.

1-3.2

Chapter 5 of this standard shall apply to control rooms that are located in Class I or Class II locations and that <u>do not contain an internal source</u> of flammable vapor, gas, or liquid.

1-3.3*

Chapter 6 of this standard shall apply to electrical instrument and process control equipment and similar enclosed equipment, such as a gas chromatograph or a gas analyzer, that <u>do contain an internal source</u> of flammable vapor, gas, or liquid.

1-3.4

Chapter 7 of this standard shall apply to analyzer rooms and buildings.

1-4* Degree of Fire or Explosion Hazard.

There are two degrees of hazard for Class I or Class II locations:

(a) Division 1, or normally flammable, combustible, or ignitible [NFPA 497A, *Recommended Practice for Classification of Class 1 Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas*, recognizes that an ignitible mixture is likely to be present continuously or intermittently under normal conditions of operation, repair, maintenance, or leakage].

(b) Division 2, or flammable, combustible, or ignitible only under abnormal conditions.

1-5 Definitions.

For the purpose of this standard, the following terms shall have the meanings given below.

Alarm.* A piece of equipment that generates a visual or audible signal that attracts attention.

Analyzer Room or Building. A specific room or building containing analyzers, one or more of which is piped to the process.

Approved. Acceptable to the “authority having jurisdiction.”

NOTE: The National Fire Protection Association does not approve, inspect or certify any installations, procedures, equipment, or materials nor does it approve or evaluate testing laboratories. In determining the acceptability of installations or procedures, equipment or materials, the authority having jurisdiction may base acceptance on compliance with NFPA or other appropriate standards. In the absence of such standards, said authority may require evidence of proper installation, procedure or use. The authority having jurisdiction may also refer to the listings or labeling practices of an organization concerned with product evaluations which is in a position to determine compliance with appropriate standards for the current production of listed items.

Authority Having Jurisdiction. The “authority having jurisdiction” is the organization, office or individual responsible for “approving” equipment, an installation or a procedure.

NOTE: The phrase “authority having jurisdiction” is used in NFPA documents in a broad manner since jurisdictions and “approval” agencies vary as do their responsibilities. Where public safety is primary, the “authority having jurisdiction” may be a federal, state, local or other regional department or individual such as a fire chief, fire marshal, chief of a fire prevention bureau, labor department, health department, building official, electrical inspector, or others having statutory authority. For insurance purposes, an insurance inspection department, rating bureau, or other insurance company representative may be the “authority having jurisdiction.” In many circumstances the property owner or his designated agent assumes the role of the “authority having jurisdiction”; at government installations, the commanding officer or departmental official may be the “authority having jurisdiction.”

Class I, Division 1. A Class I, Division 1 location is a location: (1) in which ignitable concentrations of flammable gases or vapors can exist under normal operating conditions; or (2) in which ignitable concentrations of such gases or vapors may exist frequently because of repair or maintenance operations or because of leakage; or (3) in which breakdown or faulty operation of equipment or processes might release ignitable concentrations of flammable gases or vapors and might also cause simultaneous failure of electric equipment. [See Article 500-5(a) of NFPA 70, *National Electrical Code*.]

Class I, Division 2. A Class I, Division 2 location is a location: (1) in which volatile flammable liquids or flammable gases are handled, processed, or used, but in which the liquids, vapors, or gases will normally be confined within closed containers or closed systems from which they can escape only in case of accidental rupture or breakdown of such containers or systems, or in case of abnormal operation of equipment; or (2) in which ignitable concentrations of gases or vapors that are normally prevented by positive mechanical ventilation and that might become hazardous through failure or abnormal operation of the ventilating equipment; or (3) that is adjacent to a Class I, Division 1 location and to which ignitable concentrations of gases or vapors might occasionally be communicated unless such communication is prevented by adequate positive-pressure ventilation from a source of clean air, and effective safeguards against ventilation failure are provided. [See Article 500-5(b) of NFPA 70, *National Electrical Code*.]

Class II, Division 1. A Class II, Division 1 location is a location: (1) in which combustible dust is in the air under normal operating conditions in quantities sufficient to produce explosive or ignitable mixtures; or (2) where mechanical failure or abnormal operation of machinery or equipment might cause such explosive or ignitable mixtures to be produced and might also provide a source of ignition through simultaneous failure of electric equipment, operation of protection devices, or from other causes; or (3) in which combustible dusts of an electrically conductive nature may be present in hazardous quantities. [See Article 500-6(a) of NFPA 70, *National Electrical Code*.]

Class II, Division 2. A Class II, Division 2 location is a location where combustible dust is not normally in the air in quantities sufficient to produce explosive or ignitable mixtures, and dust accumulations are normally insufficient to interfere with the normal operation of electrical equipment or other apparatus, but combustible dust may be in suspension in the air as a result of infrequent malfunctioning of handling or processing equipment and where combustible dust accumulations on, in, or in the vicinity of the electrical equipment may be sufficient to interfere with the safe dissipation of heat from electrical equipment or may be ignitable by abnormal operation or failure of electrical equipment. [See Article 500-6(b) of NFPA 70, *National Electrical Code*.]

Enclosure Volume. The volume of the empty enclosure without internal equipment.

Ignition-Capable Equipment. Equipment that, under normal operation, produces sparks, hot surfaces, or a flame that can ignite a specific flammable atmosphere.

Ignition Temperature.* The autoignition temperature of a flammable gas or vapor or the lower of either the layer ignition temperature or cloud ignition temperature of a combustible dust.

Indicator. A piece of equipment that shows flows or pressure and is monitored periodically, consistent with the requirement of the application.

Power Equipment. Equipment that utilizes power greater than 2500 VA or switches loads greater than 2500 VA.

Pressurization. The process of supplying an enclosure with a protective gas with or without continuous flow at sufficient pressure to prevent the entrance of a flammable gas or vapor, a combustible dust, or an ignitable fiber.

Pressurizing System.* A grouping of components used to pressurize and monitor a protected enclosure.

Protected Enclosure. The enclosure pressurized by a protective gas.

Protected Equipment. The electrical equipment internal to the protected enclosure.

Protective Gas. The gas used to maintain pressurization or to dilute a flammable gas or vapor.

Protective Gas Supply. The compressor, blower, or compressed gas container that provides the protective gas at a positive pressure. The supply includes inlet (suction) pipes or ducts, pressure regulators, outlet pipes or ducts, and any supply valves not adjacent to the pressurized enclosure.

Purging. The process of supplying an enclosure with a protective gas at a sufficient flow and positive pressure to reduce the concentration of any flammable gas or vapor initially present to an acceptable level.

Shall. Indicates a mandatory requirement.

Should. Indicates a recommendation or that which is advised but not required.

Specific Particle Density.* The density of individual dust particles, as opposed to the bulk density of the material.

Type X Pressurizing. Reduces the classification within the protected enclosure from Division 1 to nonclassified.

Type Y Pressurizing. Reduces the classification within the protected enclosure from Division 1 to Division 2.

Type Z Pressurizing. Reduces the classification within the protected enclosure from Division 2 to nonclassified.

Ventilated Equipment. Equipment, such as motors, that requires airflow for heat dissipation as well a pressurization to prevent entrance of flammable gases, vapors, or dusts.

Chapter 2 General Requirements for Pressurized Enclosures

2-1 Scope.

This chapter shall apply to enclosures containing electrical equipment that are located in Class I or Class II locations.

2-2 Enclosure.

2-2.1

The protected enclosure, including windows, shall be constructed of material that is not likely to be damaged under the conditions to which it may be subjected.

2-2.1.1 Precautions shall be taken to protect the enclosure from excessive pressure of the protective gas supply.

2-2.1.2 Excess pressure relieving devices, where required to protect in the case of a control failure, shall be designed to prevent escape of sparks or burning material to a Division 1 location.

2-2.2*

All cable and conduit connections to a pressurized enclosure shall be sealed as required in Sections 501-5, 502-5, or 504-70, as applicable, of NFPA 70, *National Electrical Code*.

Exception: Pressurized raceways designed in accordance with Chapter 2 and installed as part of an approved system are not required to be sealed.

2-3 Pressurizing System.

2-3.1*

The protected enclosure shall be constantly maintained at a positive pressure of at least 25 Pa (0.1 in. water) above the surrounding atmosphere during operation of the protected equipment.

2-3.2

If positive pressure is not maintained in a protected enclosure, a suitable device such as an indicator, alarm, cutoff, or interlock switch shall warn the user to take action or shall automatically de-energize power from ignition-capable equipment. The type of device should be dependent upon the type of pressurization used.

2-3.3

An alarm shall be provided to indicate failure of the protective gas supply to maintain the required pressure.

2-3.4

All components that are either not protected by the protective gas or that may be energized in the absence of the protective gas shall be approved for the classified location in which they are installed in the absence of the protective gas.

2-3.5

Adequate instructions shall be provided for the pressurization system to ensure that the system can be used properly and that the enclosure will be protected from excessive pressure.

2-4 Protective Gas System.

2-4.1*

The protective gas shall be essentially free of contaminants or foreign matter and shall contain no more than trace amounts of flammable vapor or gas. All protective gas supplies shall be carefully designed to minimize chances for contamination.

2-4.1.1* Air of normal instrument quality, nitrogen, or other nonflammable gas shall be considered acceptable as a protective gas.

2-4.2

Piping for the protective gas shall be protected against mechanical damage.

2-4.3

If compressed air is used, the compressor intake shall be located in a nonclassified location.

2-4.4*

If the compressor intake line passes through a classified location, it shall be constructed of noncombustible material, designed to prevent leakage of flammable gases, vapors, or dusts into the protective gas, and protected against mechanical damage and corrosion.

2-4.5

The electrical power for the protective gas supply (blower, compressor, etc.) shall be supplied either from a separate power source or from the protected enclosure power supply before any service disconnects to the protected enclosure.

2-4.6

When “double pressurization” is used (e.g., a Division I enclosed area pressurized to a Division 2 classification that contains ignition-capable equipment also protected by pressurization), the protective gas supplies shall be independent.

2-5 Determination of Temperature Marking.

2-5.1*

The temperature identification number (T Code) marked on the enclosure shall represent (under normal conditions) the highest of the following: (1) the hottest enclosure external surface temperature, (2) the hottest internal component surface, or (3) the temperature of the protective gas leaving the enclosure. The actual temperature in degrees Celsius may be marked in place of the T Code wherever the T Code is referenced in this standard.

Exception: Internal components may exceed the marked T Code rating if they comply with one of the following:

(a) The enclosure is marked as required in 2-11.3 with the time period sufficient to permit the component to cool to the marked T Code.

(b) The component is separately housed so that the surface temperature of the housing is below the marked T Code. This housing shall be pressurized or sealed. If the housing can be readily opened, then the housing shall be marked as required in 2-11.3.

(c) The small component has been shown not to be capable of igniting a test gas associated with a lower T Code or will not ignite the flammable vapor, gas. or dust involved.*

2-5.2*

Table 2-5.2 lists the temperature index numbers (T Codes) as defined in Article 500-3(b) of NFPA 70, *National Electrical Code*. These T Codes are based upon a 40°C ambient.

Table 2-5.2 Temperature Identification Numbers (T Codes)

Maximum Temperature		
°C	**°F**	**T Code**
450	842	T1
300	572	T2
280	536	T2A
260	500	T2B
230	446	T2C
215	419	T2D
200	392	T3
180	356	T3A
165	329	T3B
160	320	T3C
135	275	T4
120	248	T4A
100	212	T5
85	185	T6

2-6 Ventilated Equipment.

2-6.1

Discharge of the protective gas from the enclosure shall be to a nonclassified location.

Exception: The discharge may be to a Division 2 location if the equipment does not create ignition-capable particles during normal operation.

2-6.2*

The flow of protective gas shall be sufficient to keep the equipment adequately cooled.

2-7* Power Equipment.

Enclosures containing power equipment shall be of substantially noncombustible construction and shall be reasonably tight. Gaskets shall be permitted.

NOTE: Nonmetallic enclosure flammability ratings of 94 V-0 or 94 5V are considered as substantially noncombustible. (See ANSI/UL94, *Tests for Flammability of Plastic Materials,* for description of flammability ratings.)

2-8* Type Z Pressurization.

2-8.1*

Failure to maintain positive pressure within an individual protected enclosure shall be detected by an alarm or an indicator, but it is not necessary to de-energize the protected equipment.

2-8.2

Any protected enclosure that can be isolated from the protective gas supply shall be equipped with an alarm.

Exception: The protected enclosure shall be permitted to be equipped with an indicator if the isolation is done with a valve(s) that is immediately adjacent to the protected enclosure and the valve(s) is intended for use only during servicing of the protected enclosure. The valve(s) shall be marked as required in 2-11.4.

2-8.3

If an alarm is used:

(a) The alarm shall be located at a constantly attended location.

(b) The alarm actuator shall take its signal from the protected enclosure and shall not be installed between the enclosure and the protective gas supply.

(c) The alarm actuator shall be mechanical, pneumatic, or electrical.

(d) Electrical alarms and electrical alarm actuators shall be approved for the location in which they are installed.

(e) No valves shall be permitted between the alarm actuator and the enclosure.

NOTE: This alarm also satisfies the requirement in 2-3.3 to provide an alarm on the protective gas supply.

2-8.4

If an indicator is used:

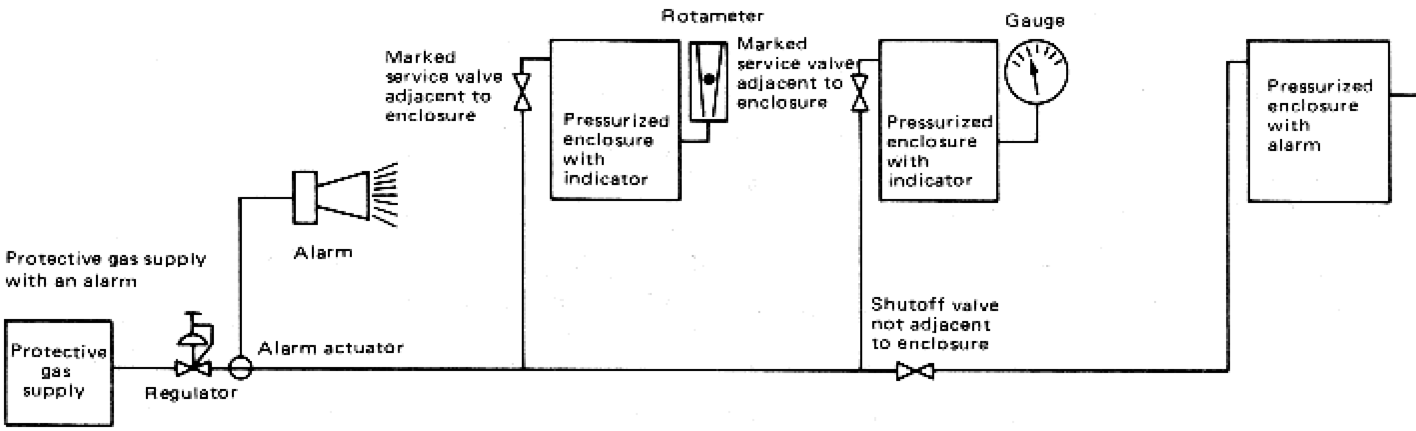
(a) The indicator shall be located for convenient viewing.

(b) The indicator shall not be installed between the enclosure and the protective gas supply.

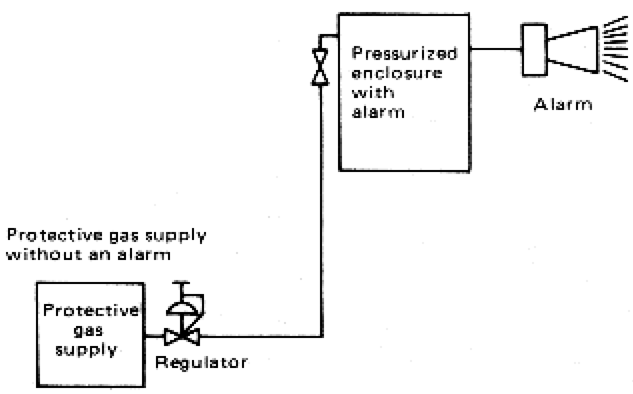
(c) The indicator shall indicate either pressure or flow.

(d) No valves shall be permitted between the indicator and the enclosure.

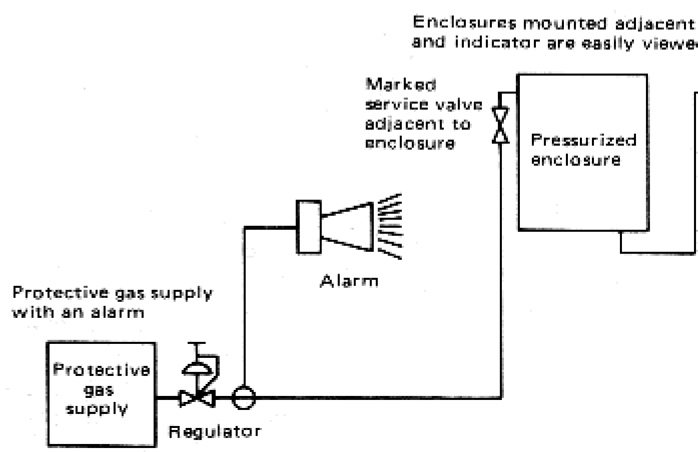
(e) The protective gas supply shall have an alarm that is located at a constantly attended location to fulfill the requirement in 2-3.3.



Example 1: Shows indicators may be used if protective gas supply has an alarm and the shutoff valve is adjacent to the enclosure.



Example 2: Shows enclosure alarm can also fulfill requirement for protective gas supply alarm.



Example 3: Shows multiple enclosures can be series purged.

Figure 2-8 Typical alarm and indicator configurations for Types Y and Z pressurization.

2-9* Type Y Pressurization

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2-9.1

All applicable requirements in Section 2-8 shall be complied with.

2-9.2

Equipment within the protected enclosure shall be approved for Division 2 locations.

2-9.3

Ventilated equipment that would develop temperatures hotter than the marked T Code rating upon failure of the ventilation shall be automatically de-energized when the flow of protective gas stops.

2-10* Type X Pressurization.

2-10.1*

A cutoff switch shall be incorporated to de-energize power automatically from all circuits within the protected enclosure not approved for Division 1 upon failure of the protective gas supply.

Exception: Power to the circuits shall be permitted to be continued for a short period if immediate loss of power would result in a more hazardous condition and if both audible and visual alarms are provided at a constantly attended location.

2-10.1.1 The cutoff switch provided to de-energize power upon failure of the protective gas supply to maintain positive pressure shall be either flow or pressure actuated.

2-10.1.2 The cutoff switch shall be approved for use in the location in which it is installed.

2-10.1.3 No valves shall be permitted between the cutoff switch and the protected enclosure.

2-10.1.4 The cutoff switch shall take its signal from the protected enclosure and shall not be installed between the enclosure and the protective gas supply.

2-10.2*

Equipment, such as motors or transformers, that may be overloaded shall be provided with appropriate devices to detect any increase in temperature of the equipment beyond its design limits and shall de-energize the equipment automatically.

Exception: Power to the circuits shall be permitted to be continued for a short period if immediate loss of power would result in a more hazardous condition and if both audible and visual alarms are provided at a constantly attended location.

2-10.3

For ventilated equipment, the flow of protective gas shall provide sufficient cooling even during overload conditions or the equipment subject to overloading shall be provided with appropriate devices to detect any increase in temperature beyond its design limits and de-energize that equipment automatically.

Exception: Power to the circuits shall be permitted to be continued for a short period if immediate loss of power would result in a more hazardous condition and if both audible and *visual alarms are provided at a constantly attended location.*

2-11 Markings.

2-11.1

A permanent label shall be mounted on the protected enclosure in a prominent location so that it is visible before the protected enclosure can be opened. Labeling shall include:

2-11.1.1 The following, or an equivalent, statement:

"WARNING—PRESSURIZED ENCLOSURE

> This enclosure shall not be opened unless the area is known to be free of flammable materials or unless all devices within have been de-energized."

2-11.1.2 The area classification for the protected enclosure.

2-11.1.3 The pressurization type, e.g. Type X, Type Y, or Type Z.

2-11.1.4 The temperature identification number (T Code) or the actual temperature in degrees Celsius as determined in Section 2-5.

Exception No. 1: The T Code marking shall not be necessary if the hottest temperature does not exceed 100°C.

Exception No. 2: For equipment marked for use in a specific gas or dust atmosphere, the T Code marking shall not be necessary when the hottest temperature does not exceed 80 percent of the ignition temperature (in degrees C) of the flammable vapor, gas, or dust involved. If the dust involved is an organic dust that may dehydrate or carbonize, then the hottest temperature may not exceed the lower of either 80 percent of the layer/cloud ignition temperature or 165°C.

2-11.2

The additional markings specified in 3-3.1 and 4-3.1 may also be included on the permanent label described in 2-11.1.

2-11.3

Where 2-5.1, Exception (a) or (b) is used, the following or equivalent statement shall appear on a permanent label:

"WARNING—HOT INTERNAL PARTS

> This enclosure shall not be opened unless the area is known to be nonflammable or unless all equipment within has been de-energized for ____________ minutes."

2-11.4

Where 2-8.2, Exception is used, the following or equivalent statement shall appear on a permanent label:

"WARNING—PROTECTIVE GAS SUPPLY VALVE

> This valve must be kept open unless the area is known to be nonflammable or unless all equipment within the protected enclosure is de-energized."

Chapter 3 Pressurized Enclosures in Class I Locations

3-1 Scope.

This chapter shall apply to enclosures containing electrical equipment that are located in Class I locations.

3-2 General Requirements.

3-2.1

All the applicable requirements of Chapter 2 shall be complied with.

3-2.2

If the enclosure has been opened or if the protective gas supply has failed to maintain the required positive pressure, the enclosure shall be purged.

3-2.3

Airflow through the enclosure during purging shall be designed to avoid air pockets.

3-2.4

Once the enclosure has been purged of flammable concentrations, only positive pressure shall be required to be maintained within the enclosure. No specific flow rate shall be required to be maintained.

3-2.5*

Compartments within the main enclosure or adjacent enclosures connected to the main enclosure shall be considered separately, and protection shall be provided by one of the following methods:

(a) The internal compartment shall be vented to the main enclosure by nonrestricted top and bottom vents, common to the main enclosure. Each vent shall provide not less than 6.5 cm^2 (1.0 sq in.) of vent area for each 6560 cm^3 (400 cu in.), with a minimum vent size of 6.3 mm ($^1/_4$ in.) diameter.

(b) The internal compartment or adjacent enclosure shall be purged in series or shall be purged separately.

(c) The equipment in the internal compartment or adjacent enclosure shall be protected by other means, e.g., explosionproof, intrinsic safety, hermetic sealing, nonincendive, encapsulation, etc.

NOTE 1: Cathode ray tubes (CRTs) are hermetically sealed components.

NOTE 2: Components with a free internal volume less than 20 cm^3 (1.22 cu in.) are not considered to be internal compartments requiring protection as long as the total volume of all such components is not a significant portion of the protected enclosure volume.

NOTE 3: Components considered to be environmentally sealed such as transistors, microcircuits, capacitors, etc., are not included in the percent of volume analysis.

3-3 Markings.

A permanent label containing the start-up conditions shall be mounted on the protected enclosure in a prominent location. The label shall contain the following, or an equivalent, statement:

> "Power shall not be restored after enclosure has been opened until enclosure has been purged for minutes at a flow rate of ____________."

NOTE: The minimum pressure may be used in place of the flow rate if the pressure is a positive indication of the correct flow.

Exception: Start-up conditions shall be permitted to alternately be mounted on an adjacent pressurizing system if referenced on the protected enclosure.

3-4* Additional Requirements for Type Y or Type Z Pressurization.

The protected equipment shall not be energized until at least four enclosure volumes of the protective gas (ten volumes for motors) have passed through the enclosure while maintaining an internal pressure of at least 25 Pa (0.1 in. water).

Exception: Equipment shall be permitted to be energized immediately if a pressure of at least 25 Pa (0.1 in. water) exists and the atmosphere within the enclosure is known to be nonflammable.

3-5 Additional Requirements for Type X Pressurization.

3-5.1

A timing device shall be used to prevent energizing of electrical equipment within the protected enclosure until at least four enclosure volumes of the protective gas (ten volumes for motors) have passed through the enclosure while maintaining an internal pressure of at least 25 Pa (0.1 in. water).

3-5.2*

If the enclosure can be readily opened without the use of a key or tools, an interlock shall be provided to immediately de-energize all circuits within the enclosure that are not approved for Division 1 locations when the enclosure is opened.

3-5.2.1 The interlock, even though located within the enclosure, shall be approved for Class I, Division 1 locations.

3-5.2.2 Protected enclosures that contain hot parts requiring a cooldown period shall not be readily opened without the use of a key or tool.

Chapter 4 Pressurized Enclosures in Class II Locations

4-1 Scope.

This chapter shall apply to enclosures containing electrical equipment that are located in Class II locations.

4-2 General Requirements.

4-2.1

All applicable requirements in Chapter 2 for each type of pressurization shall be complied with, except as modified below.

4-2.2*

If combustible dust has accumulated within the protected enclosure, the protected enclosure shall be opened and the dust removed before pressurization.

NOTE: Protected enclosures should normally be kept closed whether the equipment is in operation or not.

4-2.3

Adjacent enclosures connected to the main enclosure shall be permitted to be collectively pressurized to prevent the entrance of dust if there is adequate communication to maintain the specified pressure at all points.

4-2.4*

The protected enclosure shall be constantly maintained at a pressure above the surrounding atmosphere, dependent upon the specific particle density during operation of the protected equipment. The positive pressure shall comply with Table 4-2.4.

Table 4-2.4
Minimum Enclosure Pressure Versus Dust Density

Specific Particle Density			Minimum Pressure	
lb/cu ft	kg/m^3	Specific Gravity	in. H_2O	Pa
< 130	< 2083	< 2.083	0.1	25
> 130	> 2083	> 2.083	0.5	125

4-2.5*

If the ignition temperature of the dust is not known, maximum surface temperatures shall not exceed those stated in Table 500-3(d) of NFPA 70, *National Electrical Code*.

4-3* Markings.

A permanent label containing the start-up conditions shall be mounted on the protected enclosure in a prominent location. The label shall contain the following, or an equivalent, statement:

> "Power shall not be restored after the enclosure has been opened until combustible dusts have been removed and the enclosure repressurized."

4-4* Additional Requirements for Type X Pressurization.

An alarm, provided at a constantly attended location, shall be permitted to be used in place of the cutoff switch specified in 2-10.1 if the enclosure is tightly sealed to prevent the entrance of dust.

4-5 Additional Requirements for Ventilated Equipment.

The discharge of protective gas shall not create a combustible atmosphere by disturbing layers of dusts.

Chapter 5 Pressurized Control Rooms

5-1* Scope.

This chapter shall apply to buildings or portions of buildings commonly referred to as control rooms.

5-2 Protective Gas.

5-2.1

The protective gas shall be air.

5-2.2*

The air shall be essentially free of contaminants or foreign matter and shall contain no more than trace amounts of flammable vapor or gas.

5-2.3*

The source of air shall be determined from the nature of the process and the physical layout but shall not be from a classified location.

5-2.4

Any ducts shall be constructed of noncombustible materials. The fan suction line shall be free of leaks and shall be given suitable protection from mechanical damage and corrosion to prevent hazardous concentrations of flammable gases, vapors, or dusts from being drawn into the control room.

5-3 Considerations Relating to Positive Pressure Ventilation.

5-3.1

The following factors shall be considered in designing a control room suitable for safe operation in a hazardous (classified) location:

(a) The number of people to be housed;

(b) The type of equipment to be housed;

(c) The location of the control room relative to the direction of the prevailing wind and to the location of process units, e.g., relief valves, vent stacks, and emergency relief systems.

5-3.2*

If the control room is in a classified location, it shall be designed to minimize the entry of flammable vapors, gases, liquids, or dusts.

5-4 Requirements for Positive Pressure Air Systems.

5-4.1*

The positive pressure air system shall be capable of:

(a) Maintaining a pressure of at least 25 Pa (0.1 in. water) in the control room with all openings closed;

(b) Providing a minimum outward velocity of 0.305 m/sec (60 fpm) through all openings capable of being opened. The velocity shall be measured with all these openings simultaneously open.

A drop in pressure below the 25 Pa (0.1 in. water) specified in 5-4.1(a) is permissible while meeting the requirements of 5-4.1(b).

5-4.1.1 The positive pressure air system may include heating, ventilation, and air conditioning equipment, as well as any auxiliary equipment necessary to comply with 5-4.1.

5-4.2

If there is an air consuming device (such as a compressor or laboratory hood) in the control room, sufficient air shall be supplied to accommodate its needs as well as the needs of the positive pressure air system. Alternatively, the air supply to such a device shall be taken from a separate source.

5-4.3

The positive pressure air system shall be designed to provide the required pressure and flow rate for all areas of the control room.

5-4.4

For Type X pressurizing, a cutoff switch shall be incorporated to de-energize power automatically from all circuits within the control room not approved for Division 1 upon failure of the positive pressure air system.

Exception: Power to the circuits shall be permitted to be continued for a short period if immediate loss of power would result in a more hazardous condition.

5-4.5

For Type Y and Type Z pressurizing, power to the control room shall not be required to be de-energized upon failure of the positive pressure air system.

5-4.6*

Failure of the positive pressure air system shall be detected at the discharge end of the fan and shall activate an alarm at a constantly attended location.

5-4.7*

Provisions shall be made to energize the control room safely after interruption of the positive pressure air system. Such provisions shall include checking the atmosphere in the control room with a flammable vapor detector (*see ANSI/ISA RP12.13, Part II, "Installation, Operation and Maintenance of Combustible Gas Detection Instruments"*) to determine that the atmosphere is not flammable or removing hazardous quantities of dust.

5-4.8

The switch, electrical disconnect, and motor for the air system fan shall be approved for the location as it would be classified in the absence of positive pressure ventilation.

5-4.9

The electrical power for the positive pressure air system shall be taken off the main power line ahead of any service disconnects to the control room or shall be supplied from a separate power source.

Chapter 6 Pressurized Enclosures Having an Internal Source of Flammable Gas or Vapor

6-1 Scope.

This chapter shall apply to instruments such as gas chromatographs and gas analyzers and other enclosures that contain an internal source of flammable gas or vapor.

6-2* General Requirements.

6-2.1

The applicable requirements of Chapters 2, 3, and 4 shall apply except as modified herein.

6-2.2*

For the purpose of this chapter, every protected enclosure shall be considered to have a "normal" and an "abnormal" condition. In both conditions, the electrical equipment in the enclosure is assumed to be operating correctly. The types and magnitudes of these conditions are described below.

6-2.2.1 "Normal" shall mean the anticipated release of flammable gas or vapor within the enclosure when the system that supplies the flammable gas or vapor is operating properly. The magnitude of this anticipated release may be:

(a) None — i.e., there is no release of flammable gas or vapor; or

(b) Limited — i.e., there is release of flammable gas or vapor, but the release is limited to an amount that can be diluted by the pressurizing system to less than 25 percent of the lower flammable limit.

6-2.2.2 "Abnormal" shall mean the anticipated release of flammable gas or vapor within the enclosure when the system that supplies the flammable gas or vapor is either leaking or is otherwise operating abnormally. The magnitude of this anticipated release is:

(a) Limited — i.e., the release of flammable gas or vapor is limited to an amount that can be diluted to less than 25 percent of the lower flammable limit; or

(b) Unlimited — i.e., the release of flammable gas or vapor is of such magnitude that it cannot be diluted to less than 25 percent of the lower flammable limit.

6-2.3

If all the electrical equipment within the protected enclosure is suitable for Class I, Division 1 locations, no pressurization shall be required because of the internal source.

6-2.3.1 Precautions shall be taken if the abnormal condition release may be great enough to adversely affect an external area classification.

6-2.4*

If the electrical equipment within the protected enclosure is suitable for either Class I, Division 2 locations or nonclassified locations, the pressurization requirements shall be established according to Table 6-2.4.

Table 6-2.4 Pressurization Requirements for Enclosures Subject to Internal Release

(a)	(b)	(c)		(d)
		Pressurization Requirements for Limited Release Under Abnormal Conditions		
External Area Classification	**Internal Equipment Suitable for**	**No Release Under Normal Conditions**	**Limited Release Under Normal Conditions**	**Additional Requirements for Unlimited Release Under Abnormal Conditions**
	Class I, Div. 1	None	None	None
Class I,	Class I, Div. 2	Y	Y	None
Division 1	Nonclassified	X	X	Inert**
	Class I, Div. 1	None	None	None
Class I,	Class I, Div. 2	None	Z	None
Division 2	Nonclassified	Z	X	Inert**
	Class I, Div. 1	None	None	None
Class II	Class I, Div. 2	None	Z	None
	Nonclassified	Z	X	Inert**
	Class I, Div. 1	None	None	None*
None	Class I, Div. 2	None	Z	None*
	Nonclassified	Z	X	Inert**

* Precautions must be taken if unlimited release is large enough to alter the external area classification.
** See A-6-2.4.

6-2.4.1 To determine the pressurization requirements according to Table 6-2.4:

(a) Find the external area classification in column (a).

(b) Find the internal equipment type in column (b).

(c) Determine the pressurization requirement for limited release under abnormal conditions by using the appropriate normal condition in column (c).

(d) Determine any additional requirements from column (d) if the abnormal condition is unlimited release.

6-2.5

Protected enclosures containing an open flame shall be considered to have equipment suitable for nonclassified locations for the purposes of determining the pressurization requirement according to Table 6-2.4. The flame shall be automatically extinguished upon failure of the pressurization system regardless of pressurization type.

6-3 Specific Requirements.

6-3.1

Where a release of flammable gas or vapor within an enclosure can occur either in normal operation or under abnormal conditions, protection shall be provided by:

(a) Diluting with air to maintain the concentration of flammable gas, vapor, or mixture to less than 25 percent of its lower flammable limit, based on the lowest value of the lower flammable limit of any individual flammable gas or vapor entering the enclosure, or

(b) Diluting or pressurizing with inert gas to reduce the oxygen content in the enclosure to a level of not more than 5 percent by volume or to 50 percent of the minimum concentration of oxygen required to form a flammable mixture, whichever is lower.

6-3.2

Where the protected enclosure is located in a Class I or Class II area, the pressurizing system shall also prevent entrance of the external atmosphere by providing a minimum internal pressure of 25 Pa (0.1 in. water).

6-3.3

The locations and sizes of gas or vapor outlets in the protected enclosure shall be designed to allow effective removal of both the flammable gas or vapor and the protective gas.

6-3.3.1 Where an inert protective gas is used, the outlets shall be permitted to be closed after purging to prevent undue loss of inert protective gas, provided that this does not constitute a further danger such as inadequate flow of protective gas or excessive pressure buildup.

6-3.4

In applications where flammable mixtures shall be permitted to be piped into the enclosure through the flammable gas or vapor system, suitable precautions shall be taken to prevent propagation of an explosion back to the process equipment.

6-3.5

The flow rate of protective gas shall be sufficient to maintain the requirements of 6-3.1 and to ensure adequate mixing so that the release of a flammable gas or vapor is limited.

6-3.6

To achieve proper pressurization with air, caution is needed to ensure that the air pressure used within the enclosure does not exceed the pressure of the flammable gas or vapor system supplying the enclosure, as air could enter the process, causing possible problems such as explosive concentrations of the flammable gas or vapor, corrosion, or oxidation.

6-3.7

Precautions shall be taken to protect the enclosure from excessive pressure of the protective gas supply.

Chapter 7 Pressurized Analyzer Rooms Containing a Source of Flammable Gas, Vapor, or Liquid

7-1 Scope.

This chapter shall apply to analyzer rooms containing electrical equipment having process streams of flammable liquid, vapor, or compressed flammable gas piped into the equipment.

7-2 General.

7-2.1

If the analyzer room is in a hazardous (classified) location, it shall be designed to prevent the entry of flammable gases and vapors, flammable liquids, and combustible dusts.

7-2.2

The applicable requirements of Chapter 5 for control rooms shall apply except as modified herein.

7-2.3*

Analyzer rooms shall be separated from control rooms by distance or by a wall impermeable to vapors.

7-2.4*

Flow of air through the room shall ensure adequate air distribution. Flammable vapors shall be removed as close to their source as practical.

7-2.5

Leakage of inert gases used for purging or pressurization of enclosures in an analyzer room can deplete the room’s oxygen. Where personnel can enter the analyzer room, administrative controls combined with adequate training and safe entry procedures shall be established. Warning signs advising of the hazard of inert gas shall be posted. Inert gas shall not be used for purging an entire analyzer room where personnel shall be permitted to enter. (See NFPA 69, *Standard on Explosion Prevention Systems*.)

7-2.6

The analyzer room shall be ventilated with sufficient clean air to dilute any leakage to less than 25 percent of the lower flammable limit based on the largest single failure. (See NFPA 69, *Standard on Explosion Prevention Systems*.)

7-3 Specific Requirements.

7-3.1

Process streams shall have orifices or other flow-limiting devices on the inlets. An orifice or other flow-limiting device shall be installed on the outlet, if the outlet can constitute a source of uncontrolled leakage from the process. Orifices or other flow-limiting devices shall be located outside and close to the wall of the building or room.

7-3.2*

If flammable vapor, gas, or liquid is discharged from an enclosure (e.g., analyzer enclosure) it shall not create a hazard within the analyzer house or to the surroundings.

7-3.3

Ventilation shall adequately dilute any internal release of flammable gas or vapor. If the analyzer room is located in a hazardous (classified) location, appropriate protection shall be provided against the entry of flammable gases, vapors, liquids, or dusts.

7-3.4

Sample conditioning operations (such as heating, cooling, or drying) shall be located outside the analyzer room. Process piping within the analyzer room shall be minimized.

7-3.5

All process piping shall be equipped with shutoff valves for emergency isolation located outside of the building or room.

7-3.6

False ceilings and floors shall not be used in analyzer rooms.

7-3.7*

Ventilation fans shall be constructed to minimize the possibility of sparking.

7-3.8*

In the event of ventilation failure, an audible and visual alarm shall be activated at a constantly attended location. All electrical power to the analyzer room shall be automatically shut down, and open flames shall be automatically extinguished. Power shall not be restored until the analyzer room is free of any ignitable atmosphere mixtures.

Exception: Automatic shutdown shall not be required:

(a) If the analyzer room is classified as Division 1 and does not contain any open flames, or

(b) If the analyzer room is classified as Division 2 and does not contain any open flames and has permanently installed piping or tubing to the analyzer equipment, and any flammable vapors are vented to the outside of the room or building.

7-3.9

If gas or vapor mixtures within the flammable range must be piped to the analyzer room, suitable precautions shall be taken to prevent propagation of an explosion back to the process equipment.

Chapter 8 Referenced Publications

8-1

The following documents or portions thereof are referenced within this standard and shall be considered part of the requirements of this document. The edition indicated for each reference is the current edition as of the date of the NFPA issuance of this document.

8-1.1 NFPA Publications.

National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA

02269-9101.

NFPA 69, *Standard on Explosion Prevention Systems*, 1992 edition

NFPA 70, *National Electrical Code*, 1993 edition

8-1.2 ISA Publication.

Instrument Society of America, 67 Alexander, P.O. Box 12277, Research Triangle Park, NC 27709.

ANSI/ISA RP12.13, Part II, "Installation, Operation and Maintenance of Combustible Gas Detection Instruments"

Appendix A

This Appendix is not a part of the requirements of this NFPA document, but is included for information purposes only.

A-1-1

Electrical equipment should be located in an area having as low a degree of hazard classification as practical.

This standard does not address exclusion of flammable liquids that may be splashed or spilled on such enclosures. Where there is probability of flammable liquid exposure, additional means should be taken to avoid ingress.

A-1-3.3

The flammable gas or vapor is piped internally to the enclosure so that process parameters can be measured. The source of release could be fittings or vents. It is not intended that fumes or vapors from components within the electrical equipment be considered, e.g., from decomposing insulation.

A-1-4

The degree of hazard may be reduced from Division 1 to Division 2 or may be eliminated (i.e., Division 1 or 2 to nonhazardous) by pressurizing, provided the installations are properly designed, installed, and maintained. Information on determining the extent of hazardous (classified) locations may be found in NFPA 497A and NFPA 497B.

A-1-5 Alarm.

An alarm is intended to alert the user that the pressurizing system should be immediately repaired or the electrical equipment protected by the failed pressuring system should be removed from service.

A-1-5 Ignition Temperature.

Normally, the minimum ignition temperature of a layer of a specific dust is lower than the minimum ignition temperature of a cloud of that dust. Since this is not universally true, the lower of the two minimum ignition temperatures is listed in NFPA 497M. The autoignition temperature (AIT) is determined by ASTM D 2155, *Method of Test for Autogenous Ignition Temperatures of Petroleum Products*, or ASTM E 659, *Standard Method for Determining the Autoignition Temperature of Liquid Chemicals*.

A-1-5 Pressurizing System.

The pressurizing system may include components such as the alarm actuator, indicator, cutoff switch, or components of the protective gas supply. The components may be mounted in a separate enclosure/panel or be included within the protected enclosure.

A-1-5 Specific Particle Density.

Specific particle density (sometimes referred to as the true density) is the mass per unit volume or, more commonly, weight per unit volume and is expressed as pounds per cubic foot (kilograms per cubic meter). It refers only to the material making up the particle. The term "bulk density" is obtained by placing granular or powdered material in a specified volume and calculating the density. Bulk density includes the void space between the particles created because of the irregular particle shape. As an example, the specific particle density of sulfur is about 130 lb/cu ft while the bulk density of pulverized sulfur dust is about 50 lb/cu ft.

A-2-2.2

Pressurized raceways do not need to be sealed if they have been properly designed as part of pressurized systems with the required alarms or indicators. The exception is not meant to allow the user to install the equipment and ignore proper installation of hazardous location wiring. The exception allows the same raceway to be used for electrical wiring and the protective gas. The design must consider the restriction of protective gas flow when conductors are installed in the raceway.

A-2-3.1

The reason for requiring that a positive pressure be maintained is to prevent flammable vapors or gases from being forced into the enclosure by external air currents.

A-2-4.1

Air filtration may be desirable.

A-2-4.1.1 Ordinary plant compressed air is usually not suitable for purge or pressurizing systems, due to contaminants that may cause equipment to malfunction.

A-2-4.4

The compressor suction line should not pass through any area having a hazardous atmosphere, unless it is not practical to do otherwise.

A-2-5.1

Because a high temperature source of ignition is not immediately removed by de-energizing the equipment, additional precautions are necessary for hot components.

If the external temperature of the enclosure is greater than the autoignition temperature (in degrees Celsius) of the gas or vapor, it is obvious that purging will not prevent an explosion. Thus, it is essential that excess surface temperature be prevented, unless it has been specifically shown to be safe by a qualified testing laboratory. Dust that is carbonized or excessively dry is highly susceptible to spontaneous ignition.

Sources of internal temperatures above the autoignition temperature (in degrees Celsius) of the gas or vapor involved, such as vacuum tube filaments, are hermetically sealed to prevent them from contacting the atmosphere that may become hazardous. However, it is essential that the surface of the glass envelope does not exceed the 80 percent limit, unless shown by test to be safe.

A-2-5.1 Exception (c) The ignition temperature of gases and vapors that is listed in reference documents such as NFPA 497M is determined under conditions where a significant volume of gas is at the same temperature. When ignition is attempted with a small component, convection effects and partial oxidation at the surface of the component decrease the rate of heat transfer to the gas. Therefore, the component must be at a temperature much higher than the quoted ignition temperature to ignite the flammable mixture. Typical transistors, resistors, and similar small components must have a surface temperature of 220 to 300°C to ignite diethyl ether whose ignition temperate is 160°C. Similar values have been measured in ignition tests of carbon disulfide whose ignition temperature is 100°C.

A-2-5.2

The T Code is based upon the ambient temperature surrounding the pressurized equipment not exceeding 40°C. Higher temperatures will require adjustment of the marked T Code rating. For example, equipment marked T5 would be considered as T4A if used in a 60°C ambient. The maximum ambient temperature rating of the equipment must not be exceeded.

A-2-6.2

Airflow required for cooling may be more than that required for purging.

A-2-7

Enclosures containing power equipment are more likely to produce ignition-capable particles. It is necessary to have an enclosure that these particles will not burn through nor escape from openings other than the vents. Other techniques may be used to ensure that ignition-capable particles are contained in the enclosure.

A-2-8

Type Z pressurization reduces the classification within an enclosure from Division 2 to nonhazardous. With Type Z purging, a hazard is created only if the purge system fails at the same time that the normally nonhazardous area becomes hazardous. For this reason, it is not considered essential to remove power from the equipment upon failure of the purge system.

A-2-8.1

An alarm is preferred, but an indicator is acceptable if the protected enclosure is much less likely to fail than the protective gas supply. Excessive leakage from the protected enclosure is only likely during servicing at which time the indicator will assist the maintenance personnel in determining when the enclosure is adequately sealed to maintain pressure.

A-2-9

Type Y pressurization reduces the classification within an enclosure from Division 1 to Division 2. Equipment and devices within the enclosure must be suitable for Division 2. This requires that the enclosure does not contain an ignition source. Thus, a hazard is created within the enclosure only upon simultaneous failure of the purge system and of the equipment within the enclosure. For this reason, it is not considered essential to remove power from the equipment upon the failure of the purge system.

A-2-10

Type X pressurization reduces the classification within an enclosure from Division 1 to nonhazardous. Because the probability of a hazardous atmosphere external to the enclosure is high and the enclosure normally contains a source of ignition, it is essential that any interruption of the purging results in de-energizing of the equipment. Also, it is essential that the enclosure be tight enough to prevent escape of molten metal particles or sparks.

A-2-10.1

Power to the circuits may be continued for a short period where the Division 1 location only has a flammable concentration on an intermittent basis and where entrance of the external atmosphere would be slow because the protected enclosure is tightly sealed. Where flammable concentrations occur frequently or enclosure failure may be catastrophic, then Type Y pressurization should be used if it is necessary to continue operating the process to prevent a more hazardous condition.

A-2-10.2

Overload conditions need only be a concern where the motor load or the transformer load is not determined by the product but by external variable loading in the actual application.

A-3-2.5

In order for any internal or adjacent enclosure to be automatically purged as the main enclosure is purged, adequate vents must be provided to permit air circulation between the two enclosures. The area required to provide adequate venting will depend on the volume of the internal or adjacent enclosure. It is considered that meeting this requirement will prevent the formation of unpurged pockets of gas or vapor within the enclosure. This does not imply that internal or adjacent enclosures not meeting these requirements are prohibited but that such enclosures must be provided with their own purge system.

A-3-4

Any time the enclosure has been opened or the purge system has failed, the possibility exists that an explosive mixture may have accumulated in the enclosure. For enclosures that are effectively subdivided by internal parts, a greater purge volume may be necessary.

A-3-5.2

It is essential that any door access that can be opened by untrained personnel be protected with interlock switches. Consistent with the practice that has been established with explosionproof enclosures, it is considered that the commonly displayed warning nameplate is adequate protection for an enclosure that requires the use of a tool to be opened.

A-4-2.2

Cleaning should be done using a method that will not create a dust cloud, e.g., vacuum cleaner or brushing. Use of compressed air should be avoided.

A-4-2.4

The density of 2083 kg per m^3 (130 lb per cu ft) is slightly greater than that of sulfur dust, which was one of the dusts used in performing the tests on which the values in Table 4-2.4 are based. The pressures in the table are based on the assumption that the maximum crack width exposed to falling dust is 0.4 mm ($^1/_{64}$ in.). The ability of a dust to enter an opening due to the force of gravity against an outward velocity of gas is directly proportional to its specific particle density.

A-4-2.5

Equipment installed in Class II locations should be able to function at full rating without developing surface temperatures high enough to cause excessive dehydration or gradual carbonization of any organic dust deposits that may occur.

A-4-3

If there is not enough room on the enclosure to print the statements required in 2-11.1.1 and Section 4-3 in type large enough to be legible, equivalent wording such as the following may be used:

"De-energize before opening unless area is known to be nonhazardous. Remove dust and repressurize before restoring power."

A-4-4

A hazard is created within an enclosure only after the pressure has failed and enough dust to be explosive penetrates into the enclosure. This takes an appreciable length of time with any normally tight enclosure. Because of this, it is not always considered essential to remove the power from the equipment automatically upon failure of the pressurization. It is necessary only to provide an adequate warning so that operations will not continue indefinitely without pressurization. It is essential that the enclosure be tight enough to prevent escape of sparks or burning material.

A-5-1

Control rooms commonly house one or more of the following facilities:

(a) Process control instruments and panels;

(b) Data processing equipment;

(c) Communications equipment;

(d) Lighting, power equipment, and related equipment;

(e) Emergency power equipment;

(f) Lunch, restroom, and locker facilities;

(g) Offices and maintenance facilities;

(h) Heating and ventilating equipment.

A-5-2.2

Air filtration may be desirable.

A-5-2.3

Ordinarily, air can be taken from an area to one side of a process area where there is a minimum chance of flammable gases or vapors or combustible dusts being found. The elevation of the fan suction depends on the density of the gases, vapors, or dust under handling temperatures and adverse atmospheric conditions. For a control room in the center of a process area, ducting may be necessary.

A-5-3.2

To prevent entry of flammable vapors, gases, or dusts, positive pressure ventilation using a source of clean air may be used, and the equipment in the control room need not be housed in special enclosures. To prevent entry of flammable liquids, differences in elevation or use of dikes, etc., may be required.

A-5-4.1

A minimum number of doors should be provided so that positive pressures can be maintained, but, at the same time, the number of doors should be adequate for safe exit.

A-5-4.6

Suitable devices for detecting loss of air pressure include velocity pressure switches, static pressure switches, and plenum chambers with orifices. Electrical interlocks on the fan motor are not adequate, since belt slippage, loose impellers, or backward rotation of the fan would not be detected.

A-5-4.7

An enforced purge wherein an interlock timer requires proof of purging for a set period of time prior to energizing the control room should be considered.

A-6-2

The consequences of a release of flammable gas or vapor into an enclosure are substantially more serious than a similar release to the open atmosphere. Through the use of a purge system, these consequences may be minimized, and electrical equipment not otherwise acceptable for a flammable atmosphere may be utilized.

The effect of a temporary leak in the open is a transient rise in concentration of flammable gas or vapor in the atmosphere. A leak inside an enclosure, in the absence of purging, remains within the enclosure and if undetected will slowly raise the concentration inside the enclosure until its atmosphere becomes flammable. This increase in concentration is likely to be slowed only slightly by breathing and diffusion.

A-6-2.2

Because of the confining property of electrical equipment enclosures, it is necessary to view “normal” and “abnormal” conditions in terms of a longer time span than is necessary in considering releases in the open. Normal must include consideration of the probable operation of the apparatus after some years of service and includes degradation of the system components over time.

For no release within an enclosure under normal conditions, there must be a minimum risk (i.e., very low probability) that flammable material will escape from its containment system during the time the apparatus is in service and within the range of service conditions to which it is likely to be subjected. Therefore, materials and types of construction that degrade in service or with age and that are not likely to be maintained or replaced cannot be considered to permit a “normal condition—no release” as defined in 6-2.2.

Although specific rules that will apply to all designs cannot be written, in general, a design will be considered to have no normal release: if the flammable gas or vapor is enclosed in metallic pipes, tubes, vessels, or elements such as bourdons, bellows, or spirals; in systems that contain no moving seals; and if prototype systems do not leak when tested at 1.5 times their rated pressure, except in cases where another safety factor is applicable. Joints made with pipe threads, welding, metallic compression fittings, or other equally reliable methods would usually be considered to have no normal release.

Windows, elastomeric seals, and nonmetallic flexible tubing would in most cases not meet the requirement for “normal condition—no release” unless it can be demonstrated that time and environment will not degrade them below the leakage level expected of the operating pipe threads and compression seals. Systems that cannot meet a stringent interpretation of these guidelines should be considered “normal condition—limited release.” Seals, rotating or sliding seals, flanged joints, and flexible nonmetallic tubing can be assumed to leak minutely after a period of service.

Attention must be given to the possibility that expected degradation of components may result in release of flammable gas or vapor at a rate faster than that which the dilution system can handle. Such situations are not common but, when encountered, they should not be classified as “normal condition—limited release.” The prime criterion for “normal condition—limited release” is that the dilution capability of the protective system must not be exceeded.

In enclosures having open flames in normal operation, it is assumed that flame extinguishment is a normal occurrence and should be classified as a normal release unless loss of flame automatically stops the flow of flammable gas or vapor.

A limited abnormal release is one that, by design, is maintained at a level within the dilution capability of the protective system. The limiting element may be a restriction in the flow line. In the case of designs using elastomeric seals, the limiting flow may be considered to be the flow that would exist were the seal not in place.

A-6-2.4

Electrical equipment permitted in nonhazardous (nonclassified) locations may contain arcing or sparking contacts or may have hot surfaces. If there is no normal release within the equipment enclosure, a single failure of the system containing the flammable gas will provide the flammable atmosphere. The ignition source is always present, by virtue of the electrical equipment. Purging is, therefore, required, and Type Z purging will provide adequate protection. If, however, there is a limited release under normal conditions and there is limited release under abnormal conditions, then Type X purging is required. In this case, purging with air is satisfactory. Type X purging requires that the electrical power to the purged enclosure be disconnected upon failure of the purge system. Disconnection is required because, under the conditions described, a flammable atmosphere will be generated in the presence of arcing or sparking equipment or hot surfaces.

Electrical equipment suitable for Division 2 locations may present a source of ignition only upon failure or other abnormal conditions. If there is no normal release within the equipment enclosure, no purging is required because there is not normally a source of ignition present, even if the system containing the flammable gas fails. If there is limited normal release and limited abnormal release, then Type Z purging, with air, provides adequate protection. If, however, the abnormal release is unlimited (i.e., beyond the dilution from a single failure of the containment system); therefore, air is not permitted as the purge gas for such enclosures when the electrical equipment is only suitable for nonclassified locations. Inert gas must be used so that a flammable atmosphere is prevented from developing (unless, of course, the purge system itself fails).

For an air-purged enclosure containing equipment suitable for Division 2 locations, although an unlimited abnormal release results in a flammable atmosphere, the electrical equipment is assumed to be operating normally and, therefore, does not present a source of ignition. However, if a failure of the containment system is not obvious, inert gas purging should be used because of the danger that a flammable atmosphere may exist for a prolonged period of time, during which the electrical equipment may also fail and provide the source of ignition.

Whether electrical equipment is located in a Division 2 or a nonclassified location does not affect the need for a purge system. For Division 2 locations, the purge system serves two purposes: (1) to prevent the external atmosphere from entering the enclosure, and (2) to dilute any flammable gas released within the enclosure. In a nonclassified location, the purge system serves only to dilute any flammable gas released within the enclosure.

A-7-2.3

Flammable gases, vapors, or liquids for analysis should not be piped into control rooms because of the danger of ignition.

A-7-2.4

Flammable hydrocarbon vapors are usually heavier than air and should be removed at floor level. Lighter-than-air gases such as hydrogen and methane should be removed at the ceiling level.

A-7-3.2

Flammable gases or vapors should be discharged at a safe point outside the analyzer room in an upward or horizontal direction to aid in dispersion. The vent discharge should be located at least 5 ft (1.5 m) away from building openings and at least 12 ft (3.7 m) above grade level. The vent design and location should further consider possible trapping of vapors by eaves or other obstructions. (See NFPA 30, *Flammable and Combustible Liquids Code*.)

A-7-3.7

The fan motor and associated control equipment should be located external to the ductwork or should be suitable for the location.

A-7-3.8

It is assumed that the flow of flammable vapors or liquids will continue in case of failure of the ventilation system and that the atmosphere in the analyzer room will reach the flammable range. In these situations, power must be removed to avoid ignition.

Appendix B Referenced Publications

B-1

The following documents or portions thereof are referenced within this standard for informational purposes only and thus are not considered part of the requirements of this document. The edition indicated for each reference is the current edition as of the date of the NFPA issuance of this document.

B-1.1 NFPA Publications.

National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.

NFPA 30, *Flammable and Combustible Liquids Code*, 1990 edition

NFPA 497A, *Recommended Practice for Classification of Class I Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas*, 1992 edition

NFPA 497B, *Recommended Practice for Classification of Class II Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas*, 1991 edition

NFPA 497M, *Manual for Classification of Gases, Vapors, and Dusts for Electrical Equipment in Hazardous (Classified) Locations*, 1991 edition

B-1.2 ASTM Publications.

American Society for Testing and Materials, 1916 Race St., Philadelphia, PA 19103.

ASTM E 659-78 (1984), *Standard Method for Determining the Autoignition Temperature of Liquid Chemicals*

ASTM D 2155-66 (1976), *Method of Test for Autogenous Ignition Temperatures of Petroleum Products*

B-1.3 UL Publication.

Underwriters Laboratories, 333 Pfingsten Road, Northbrook, IL 60062.

ANSI/UL94, *Tests for Flammability of Plastic Materials*

B-1.4 Other Publications.

Dorsett, H.G., et al., *Laboratory Equipment and Test Procedures for Evaluating Explosibility of Dusts*, RI 5624, U.S. Bureau of Mines, Pittsburgh, PA 1960

Electrical Safety Practices, Monograph 112 (1969), McCarron, R., *Report of an Investigation of the Effect of Internal Arcing versus External Spot Temperatures of Metal Instrument Cases*, Instrument Society of America, Pittsburgh, PA

Zenz, F.A. & Othmer D.F. *Fluidization & Fluid Particle Systems* (1960) Reinhold

Perry, R.H. & Green, D. *Chemical Engineer's Handbook* 6th Edition (1984) McGraw-Hill

Formal Interpretation

NFPA 496

Purged and Pressurized Enclosures for Electrical Equipment

1993 Edition

Reference : 3-3.1
F.I.

Paragraph 3-3.1 requires a positive pressure purge system to:

(a) Be capable of maintaining a pressure of at least 25 Pascals (0.1 in. of water) in the control room with all openings closed.

(b) Be capable of providing a minimum outward velocity of 0.305 m/sec (60 ft per min) through all openings capable of being opened. The velocity shall be measured with all three openings simultaneously open. A drop in pressure below the 25 Pascals (0.1 in. of water) specified in 5-4.1(a) is permissible while meeting 5-4.1(b).

Question: Is it the intent of 3-3.1 to require that the purge system function as "a" and "b" simultaneously?

Answer: No.

Issue Edition: 1974
Reference:– 3-3.1
Date: December 1977

NFPA 497A

1992 Edition

Recommended Practice for Classification of Class I Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas

1992 Edition

This edition of NFPA 497A, *Recommended Practice for Classification of Class I Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas*, was prepared by the Technical Committee on Electrical Equipment in Chemical Atmospheres and acted on by the National Fire Protection Association, Inc. at its Fall Meeting held November 18-20, 1991 in Montréal, Québec, Canada. It was issued by the Standards Council on January 17, 1992, with an effective date of February 10, 1992, and supersedes all previous editions.

The 1992 edition of this document has been approved by the American National Standards Institute.

Changes other than editorial are indicated by a vertical rule in the margin of the pages on which they appear. These lines are included as an aid to the user in identifying changes from the previous edition.

Origin and Development of NFPA 497A

The Committee on Electrical Equipment in Chemical Atmospheres began the development of this recommended practice in 1973. The Committee based the diagrams in this document on various codes and standards of the National Fire Protection Association and on the accepted practices of the chemical process industries and the petroleum refining industry. The first edition of this recommended practice was adopted by the Association at the 1975 Annual Meeting.

The Committee began a thorough review of this document in 1980 and completed its work in 1985. The designation was changed to NFPA 497A in anticipation of a similar recommended practice for Class II hazardous (classified) locations.

In 1989 the Technical Committee on Electrical Equipment in Chemical Atmospheres recognized a need for editorial revisions to the drawings referenced in Section 3-4. There were also new drawings included for flammable liquid tank truck loading and unloading and for marine terminal handling of flammable liquids.

Technical Committee on Electrical Equipment in Chemical Atmospheres

R. F. Schwab, *Chairman*
Allied-Signal, Inc.

Mark C. Ode, *Secretary*
National Fire Protection Association, MA
(Nonvoting)

Alonza W. Ballard, Crouse-Hinds ECM
Rep. National Electrical Manufacturers Assoc.

Albert A. Bartkus, Underwriters Laboratories Inc.

Michael K. Baucom, BEBCO Industries, Inc.

Carol M. Boring, U.S. Dept. of Labor

David H. Byford, Unocal Corp.
Rep. American Petroleum Institute

William G. Lawrence, Factory Mutual Research Corp.

Richard Y. LeVine, Stamford, CT

Ernest C. Magison, Honeywell Inc.
Rep. Instrument Society of America

NFPA 497A
Recommended Practice for
Classification of Class I Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas

1992 Edition

Information on referenced publications can be found in Chapter 4 and Appendix A.

Chapter 1 General

1-1 Scope.

1-1.1

This recommended practice applies to those locations where flammable gases or vapors, flammable liquids, or combustible liquids are processed or handled and where their release into the atmosphere may result in their ignition by electrical systems or equipment.

1-1.2

This recommended practice applies to chemical process areas. As used in this recommended practice, a chemical process area may be a large integrated chemical process plant or it may be a part of such a plant. It may be a part of a manufacturing facility where flammable gases or vapors, flammable liquids, or combustible liquids are produced or used in chemical reactions or are handled or used in certain unit operations such as mixing, filtration, coating, spraying, distillation, etc.

1-1.3

This recommended practice does not apply to situations that may involve catastrophic failure of or catastrophic discharge from process vessels, pipelines, tanks, or systems.

1-1.4

This recommended practice does not apply to situations involving enriched oxygen atmospheres. It also does not apply to situations involving pyrophoric materials.

1-1.5

This recommended practice is not intended to supersede or conflict with applicable requirements of the following:

NFPA 30, *Flammable and Combustible Liquids Code*;

NFPA 33, *Standard for Spray Application Using Flammable and Combustible Materials*;

NFPA 34, *Standard for Dipping and Coating Processes Using Flammable or Combustible Liquids*;

NFPA 35, *Standard for the Manufacture of Organic Coatings*;

NFPA 36, *Standard for Solvent Extraction Plants*;

NFPA 45, *Standard on Fire Protection for Laboratories Using Chemicals*;

NFPA 50A, *Standard for Gaseous Hydrogen Systems at Consumer Sites*;

NFPA 50B, *Standard for Liquefied Hydrogen Systems at Consumer Sites*;

NFPA 58, *Standard for the Storage and Handling of Liquefied Petroleum Gases*; and

NFPA 59A, *Standard for the Production, Storage, and Handling of Liquefied Natural Gas (LNG)*.

1-2 Purpose.

1-2.1

It is the intent of this recommended practice to provide the user with a basic understanding of the parameters that determine the degree and the extent of the hazardous (classified) location. This recommended practice also provides the user with examples of the application of these parameters.

1-2.2

This recommended practice is intended as a guide and should be applied with sound engineering judgment. When all factors are properly evaluated, a consistent area classification scheme can be developed.

1-3 *National Electrical Code*® Criteria.

This recommended practice is based on the criteria established by Article 500 of NFPA 70, *National Electrical Code*, but is not intended to supercede or conflict with the requirements therein. Once an area is properly classified, the *National Electrical Code* specifies the type of equipment and the wiring methods that may be used.

Chapter 2 Basic Considerations

2-1 *National Electrical Code* Criteria.

2-1.1

Article 500 of NFPA 70, *National Electrical Code*, designates as hazardous (classified) any location in which a combustible material is or may be present in the atmosphere in sufficient concentration to produce an ignitible mixture. Article 500 defines three major categories of hazardous location:

(a) Class I, in which the combustible material is a gas or vapor;

(b) Class II, in which the combustible material is a dust;

(c) Class III, in which the combustible material is a fiber or flying.

This recommended practice is limited to Class I hazardous (classified) locations.

2-1.2

The intent of Article 500 is that electrical equipment and systems in hazardous (classified) locations should not provide a means of ignition for an ignitible mixture that may be present.

2-1.3

Within each class, Article 500 recognizes two degrees of hazard: Division 1 and Division 2. In Division 1, an ignitible mixture is likely to be present continuously or intermittently under normal conditions of operation, repair, maintenance, or leakage. In Division 2, an ignitible mixture is likely to be present under abnormal operating conditions, such as failure of process equipment.

2-1.3.1 Electrical installations in Division 1 locations are designed so that normal operation or failure of any part of the electrical system will not release flame, sparks, or hot gases, nor will it result in surface temperatures high enough to ignite the surrounding atmosphere.

2-1.3.2 Installations for Division 2 locations are designed and arranged so that normal operation of the electrical system does not provide a source of ignition. Protection against ignition during electrical breakdown is *not* provided. However, electrical breakdowns are sufficiently rare that the chances of one occurring simultaneously with accidental release of an ignitible mixture are extremely remote. Arcing and sparking devices are permitted only if suitably enclosed or if the sparks are of insufficient energy to ignite the mixture.

2-1.4

Electrical installations for areas classified as hazardous may be designed in various manners. No single manner is best in all respects or for all types of equipment used in a chemical process plant. Explosionproof electrical equipment, Types X, Y, and Z purged electrical equipment, and intrinsically safe electrical equipment are applicable to both Division 1 and Division 2 locations. Nonsparking electrical equipment and other less restrictive equipment, as specified in NFPA 70, *National Electrical Code*, are permitted in Division 2 locations.

2-1.5

Factors such as corrosion, weather, maintenance, equipment standardization and interchangeability, and possible process changes or expansion frequently dictate the use of special enclosures or installations for electrical systems. However, such factors are outside the scope of this recommended practice, which is concerned entirely with the proper application of electrical equipment to avoid ignition of flammable mixtures.

2-1.6

Locations that do not need to be classified as Division 1 or Division 2 are “nonclassified.”

2-2 Conditions Necessary for Ignition.

2-2.1

In a Class I location, three conditions must be satisfied for ignition to occur:

(a) A combustible gas or vapor must be present.

(b) The gas or vapor must be mixed with air in the proportions required to produce an ignitible mixture. Further, within the context of this recommended practice, a sufficient quantity of this mixture must be present in the atmosphere surrounding the electrical equipment.

(c) There must be a release of energy intense enough to cause ignition of the mixture. Within the context of this recommended practice, the energy release is understood to originate within the electrical system.

2-2.2

In classifying a particular location, the first condition, presence of a combustible gas or vapor, is significant in determining the correct division. As described in 2-1.3, the presence of an ignitible mixture during normal conditions of operation, repair, maintenance, or leakage of the process equipment, either continuously or intermittently, calls for a Division 1 classification. In other words, combustible gas or vapor is assumed to be present at any time; all that is necessary for electrical ignition is failure of the electrical system. If combustible gas or vapor is only present as a result of abnormal operation or breakdown of equipment, then the location is designated Division 2; ignition will only occur if there is simultaneous failure of the electrical system and the equipment.

2-2.3

The second condition, presence of an ignitible mixture, is important in determining the boundaries of the hazardous location, i.e., how far it extends. The quantity of material that may be released, its physical and chemical properties, and the natural tendency of gases and vapors to disperse all must be recognized.

2-3 Behavior of Gases, Vapors, and Liquids.

2-3.1 Lighter-than-Air Gases.

Gases whose densities are less than that of air will tend to dissipate rapidly once released to the atmosphere. They will not affect as great an area as heavier-than-air gases or vapors. Except in enclosed spaces, such gases seldom accumulate to form an ignitible mixture near grade level, where most electrical installations are located.

2-3.2 Heavier-than-Air Gases.

Gases whose densities at ambient temperature are greater than that of air tend to fall to grade level when released from a container. Under stagnant conditions, diffusion is slow and depends on the particular characteristics of the gas. The gas may remain for a significant period of time, unless disturbed by natural or forced ventilation, which will assist the dispersion process.

2-3.2.1 As the gas diffuses into the surrounding air, the density of the mixture approaches that of air.

2-3.2.2 The temperature of a gas as it leaves its container must be considered. A heavier-than-air gas may have been heated sufficiently to decrease its density so that on release it behaves as a lighter-than-air gas until cooled by the surrounding atmosphere. Conversely, a lighter-than-air gas may have been cooled sufficiently to behave as a heavier-than-air gas until it absorbs heat from the surrounding atmosphere.

2-3.3 Compressed Liquefied Gases.

These gases are stored above their normal boiling point but kept in the liquid state by pressure. When released from this pressure, the liquid immediately expands and vaporizes, creating large volumes of cold gas. The cold gases behave like heavier-than-air gas, until they warm, mix with air, and dissipate.

2-3.4 Cryogenic Liquids and Other Cold Liquefied Flammable Gases.

Cryogenic liquids are generally handled below –101°C (–150°F). Those that are combustible, such as hydrogen, carbon monoxide, and natural gas, behave like flammable liquids when they are spilled. Small spills will immediately vaporize, but larger spills will remain in the liquid state, spreading horizontally and freezing the ground beneath, thus inhibiting heat transfer. As the liquid absorbs heat, it vaporizes and rises. This results in a vertical cylinder of gas in the ignitable range that diffuses as it rises.

Some liquefied flammable gases are stored at low temperatures [above –101°C (–150°F)] and pressures close to atmospheric. These materials will behave as described above. Examples of such gases are anhydrous ammonia, propane, ethane, ethylene, and propylene.

2-3.5 Flammable and Combustible Liquids.

Flammable and combustible liquids are categorized by NFPA 30, *Flammable and Combustible Liquids Code*, as follows:

(a) Class I: those having flash points below 100°F (37.8°C);

(b) Class II: those having flash points at or above 100°F (37.8°C) and below 140°F (60°C);

(c) Class III: those having flash points at or above 140°F (60°C).

2-3.5.1 When released in appreciable quantity, a Class I liquid will begin to evaporate at a rate that depends on its volatility: the lower the flash point, the greater the volatility; hence, the faster the evaporation. The vapors of Class I liquids form ignitible mixtures with air at ambient temperatures more or less readily. Even when evolved rapidly, the vapors tend to disperse rapidly, becoming diluted to a concentration below the lower flammable limit. Until this dispersion takes place, however, these vapors will behave like heavier-than-air gases. Class I liquids normally will produce ignitible mixtures that will travel some finite distance from the point of origin; thus, they will normally require area classification for proper electrical system design.

2-3.5.2 With Class II liquids, the degree of hazard is lower because the vapor release rate is low at the normal handling and storage temperatures. In general, these liquids will not form ignitible mixtures with air at ambient temperatures unless heated above their flash points. Also, the vapors will not travel as far because they tend to condense as they are cooled by ambient air. Class II liquids should be considered capable of producing an ignitible mixture near the point of release when handled, processed, or stored under conditions where the liquid may exceed its flash point.

2-3.5.3 Class III liquids are subdivided into two classes: IIIA and IIIB. Class IIIA liquids have flash points at or above 140°F (60°C) but below 200°F (93.4°C). These liquids do not form ignitible mixtures with air at ambient temperatures unless heated above their flash points. Furthermore, the vapors cool rapidly in air and condense. Hence, the extent of the area requiring electrical classification will be very small or nonexistent.

Class IIIB liquids have flash points at or above 200°F (93.4°C). These liquids seldom evolve enough vapors to form ignitible mixtures even when heated and are seldom ignited by properly installed and maintained general purpose electrical equipment.

2-3.5.4 The density of air saturated with combustible vapor at ambient temperature is generally less than 1.5 times the density of air. However, when the vapor is diluted with enough air to form an ignitible mixture, the density of the mixture approaches that of air.

2-4 Division 1 Classified Locations.

2-4.1

The decision to classify a location as hazardous is based upon the possibility that a flammable mixture may be present. Having decided that a location should be classified, the next step is to determine the degree of hazard: Is the location Division 1 or Division 2?

2-4.2

As stated in 2-1.3, a condition for Division 1 is whether the location is likely to have an ignitible mixture present under normal conditions. For instance, the presence of flammable vapors in the vicinity of open-dome loading of flammable liquid tank trucks is normal and requires a Division 1 classification.

2-4.3

Normal does not necessarily mean the situation that prevails when everything is working properly. For instance, there may be cases in which frequent maintenance and repair are necessary. These are viewed as normal and, if quantities of flammable liquid, gas, or vapor are released as a result of the maintenance, the location is Division 1. However, if repairs are not usually required between turnarounds, the need for repair work is considered abnormal. In any event, the classification of the location, as related to equipment maintenance, is influenced by the maintenance procedures and frequencies.

2-5 Division 2 Classified Locations.

2-5.1

The criterion for a Division 2 location is whether the location is likely to have ignitible mixtures present only under abnormal conditions. The term "abnormal" is used here in a limited sense and does not include a major catastrophe.

2-5.2

As an example, consider a vessel containing liquid hydrocarbons (the source) that releases flammable material only under abnormal conditions. In this case, there is no Division 1 location because the vessel is normally tight. To release vapor, the vessel would have to leak, and that would not be normal. Thus, the vessel is surrounded by a Division 2 location.

2-5.3

Process equipment does not fail often. Furthermore, the electrical installation requirements of NFPA 70, *National Electrical Code*, for Division 2 locations are such that an ignition-capable spark will occur only in the event of a breakdown of the electrical system. Otherwise, any spark will be contained within a suitable enclosure. On a realistic basis, the possibility of simultaneous failure of operating equipment and electrical equipment is very remote; this justifies the recognition and acceptance of the Division 2 concept.

2-5.4

The Division 2 classification is equally applicable to conditions not involving equipment failure. For example, consider a location classified as Division 1 because of the normal presence of an ignitible mixture. Obviously, one side of the Division 1 boundary cannot be normally hazardous and the opposite side never hazardous. Therefore, a surrounding Division 2 location separates the Division 1 location from the nonhazardous location. Another example would be a point emission source that releases combustible vapors during normal operation. This source is surrounded by a Division 1 location that, in turn, is surrounded by a larger, concentric Division 2 location. Division 2 is the transition zone, and the area outside the Division 2 location is not classified.

2-5.5

In cases in which an unpierced barrier, such as a blank wall, completely prevents the spread of gas or vapor, area classification does not extend beyond the barrier.

2-6 Nonclassified Locations.

2-6.1

Experience has shown that the release of ignitible mixtures from some operations and apparatus is so infrequent that area classification is not necessary. For example, it is not usually necessary to classify the following locations where combustible materials are processed, stored, or handled:

(a) Locations that are adequately ventilated, where combustible materials are contained within suitable, well-maintained, closed piping systems.

(b) Locations that are not adequately ventilated but where piping systems are without valves, fittings, flanges, and similar accessories that may be prone to leaks.

(c) Locations where combustible materials are stored in suitable containers.

2-6.2

Adequate ventilation is defined by NFPA 30, *Flammable and Combustible Liquids Code*, as that which is sufficient to prevent accumulation of significant quantities of vapor-air mixtures in concentrations over 25 percent of the lower flammable limit.

2-6.3

An adequately ventilated location is one of the following:

(a) An outside location.

(b) A building, room, or space that is substantially open and free of obstruction to the natural passage of air, either vertically or horizontally. Such locations may be roofed over with no walls, may be roofed over and closed on one side, or may be provided with suitably designed windbreaks.

(c) An enclosed or partly enclosed space provided with mechanical ventilation equivalent to natural ventilation. The mechanical ventilation system must have adequate safeguards against failure.

2-6.4

Open flames and hot surfaces associated with the operation of certain equipment, such as boilers and fired heaters, provide inherent thermal ignition sources. Electrical classification is not appropriate in the immediate vicinity of these facilities. Consideration should be given, however, to potential leak sources in pumps, valves, etc., or in waste product and fuel lines feeding flame- or heat-producing equipment to avoid installing electrical devices, which could then become primary ignition sources for such leaks.

2-7 Extent of Classified Location.

2-7.1

The extent of a Division 1 or Division 2 location requires careful consideration of the following factors:

(a) The flammable or combustible material;

(b) The vapor density of the material;

(c) The temperature of the material;

(d) The process or storage pressure;

(e) The size of release;

(f) The ventilation.

2-7.2

The first step is to identify the materials being handled and their vapor densities. Hydrocarbon vapors and gases are generally heavier than air, while hydrogen and methane are lighter than air. The following guidelines apply:

(a) In the absence of walls, enclosures, or other barriers, and in the absence of air currents or similar disturbing forces, the gas or vapor will disperse. Heavier-than-air vapors will travel primarily downward and outward; lighter-than-air vapors will travel upward and outward. If the source of the vapors is a single point, the horizontal area covered by the vapor will be a circle.

(b) For heavier-than-air vapors released at or near grade level, ignitible mixtures are most likely to be found below grade level; next most likely at grade level; with decreasing likelihood of presence as height above grade increases. In the open, away from the immediate point of release, freely drifting gases or vapors from a source near grade have seldom reached ignition sources at elevations more than 6 or 8 ft (1.8 to 2.4 m) above grade. For lighter-than-air gases, the opposite is true: there is little or no hazard at and below grade but greater hazard above grade.

(c) In cases where the source of vapor is above grade or below grade or in cases where the gas or vapor is released under pressure, the limits of the classified location are altered substantially. Also, a very mild breeze may extend these limits. However, a stronger breeze may accelerate dispersion of gases or vapors so that the extent of the classified location is greatly reduced. Thus, dimensional limits recommended for Division 1 or Division 2 zones must be based on experience rather than relying solely on the theoretical diffusion of vapors.

2-7.3

The degree to which air movement and material volatility combine to affect the extent of the classified location can be illustrated by two experiences monitored by combustible gas detectors. Gasoline spilled in a sizeable open manifold pit gave no indication of ignitible mixtures beyond 3 or 4 ft (0.9 to 1.2 m) from the pit when the breeze was 8 to 10 mph (13 to 16 km/hr). A slightly smaller pool of a more volatile material, blocked on one side, was monitored during a gentle breeze. At grade, vapors could be detected for approximately 100 ft (30 m) downwind; however, at 18 in. (46 cm) above grade there was no indication of vapor as close as 30 ft (9 m) from the pool.

These examples show the great variability that may be present in situations of this type and points out again that careful consideration must be given to a large number of factors when classifying areas.

2-7.4

The size of a building and its design may influence considerably the classification of the enclosed volume. In the case of a small inadequately ventilated sampling or testing room, it may be appropriate to classify the entire internal volume as Division 1.

2-7.5

When classifying buildings, careful evaluation of prior experience with the same or similar installations should be made. It is not enough to merely identify a potential source of vapor within the building and proceed immediately to defining the extent of a Division 1 or Division 2 location. Where experience indicates that a particular design concept is sound, a more hazardous classification for similar installations is not justified. Furthermore, it is conceivable that a location might be reclassified from Division 1 to Division 2, or from Division 2 to nonhazardous, based on experience.

2-7.6

Correctly evaluated, an installation will be found to be a multiplicity of Division 1 locations of very limited extent. Probably the most numerous of offenders are packing glands. A packing gland leaking a quart per minute (360 gallons per day) (0.95 liter per minute) would certainly not be commonplace. Yet, if a quart bottle were emptied each minute outdoors, the zone made hazardous would be difficult to locate with a combustible gas detector.

2-7.7

The volume of liquid or vapor released is of extreme importance in determining the extent of a hazardous location, and it is this consideration that necessitates the greatest application of sound engineering judgment. However, one cannot lose sight of the purpose of this judgment: the location is classified solely for the installation of electrical equipment.

Chapter 3 Determining the Degree and Extent of Hazardous (Classified) Locations

3-1 Diagrams and Recommendations.

3-1.1

This chapter contains a series of diagrams that illustrate the recommended extent of classified locations around typical sources of flammable gases or vapors. These locations may be assumed to contain an ignitible atmospheric mixture under the conditions described. Some of the diagrams are for single-point sources; others apply to multiple sources in an enclosed space or in an operating area. The bases for the diagrams are explained in Section 3-2.

3-1.2

The intended use of the diagrams is to aid in developing electrical classification maps of operating units, process plants, or buildings. Elevations or sectional views may be required where different classifications apply at different levels.

3-1.3

An operating unit will have many interconnected sources of combustible material, including pumps, compressors, vessels, tanks, and heat exchangers. These will, in turn, present sources of leaks such as flanged and screwed connections, fittings, valves, meters, etc. Thus, considerable judgment will be required to establish the boundaries of the Division 1 and Division 2 locations.

3-1.4

In some cases, individual classification of a multitude of point sources within an operating unit is neither feasible nor economical. In such cases, the entire unit may be classified as a single source entity. However, this should be considered only after a thorough evaluation of the extent and interaction of the various sources, both within the unit and adjacent to it.

3-1.5

In developing these diagrams, vapor density is generally assumed to be greater than that of air. Lighter-than-air gases, such as hydrogen and methane, will quite readily disperse, and the diagrams for lighter-than-air gases should be used. However, if such gases are being evolved from the cryogenic state (i.e., liquefied hydrogen or LNG), caution must be exercised because, for some finite period of time, these gases will be heavier than air due to their low temperature when first released.

3-2 Bases for Recommendations.

3-2.1

The practices of the petroleum refining industry are published in the American Petroleum Institute's RP 500A, *Classification of Locations for Electrical Installations in Petroleum Refineries*. These practices are based on a survey and an analysis of the practices of a large segment of the industry, experimental data, and careful weighing of pertinent factors. Refinery operations are characterized by the handling, processing, and storage of large quantities of materials, often at elevated temperatures. The recommended limits of classified locations for refinery installations may therefore be stricter than are warranted for more traditional chemical processing facilities that handle smaller quantities.

3-2.2

Various codes, standards, and recommended practices of the National Fire Protection Association include recommendations for classifying hazardous locations. These recommendations are based on many years of experience. NFPA 30, *Flammable and Combustible Liquids Code*, and NFPA 58, *Standard for the Storage and Handling of Liquefied Petroleum Gases*, are two of these documents.

3-2.3

Continuous process plants and large batch chemical plants may be almost as large as refineries and should, therefore, follow the practices of the refining industry. The volume of leakage from pump and agitator shaft packing glands, piping flanges, and valves increases proportionately with process equipment size and flow rate, as does the travel distance and area of dispersion from the discharge source. Similarly, the volume of the leakage, the travel distance, and the area of dispersion all increase as operating pressure increases.

3-2.4

In deciding whether to use an overall plant classification scheme or individual equipment classification, process equipment size, flow rate, and pressure should be taken into consideration. Generally speaking, for small or batch chemical plants, point source diagrams can be used; for large, high pressure plants, the API recommendations are more suitable. Table 3-2 gives ranges of process equipment size, pressure, and flow rate for equipment and piping handling flammable or combustible liquids or gases.

3-2.5

The great majority of chemical plants fall in the moderate range of size, pressure, and flow rate for equip- ment and piping handling flammable or combustible liquids or gases. However, since all cases are not the same, sound engineering judgment is required.

Table 3-2 Relative Magnitudes of Process Equipment and Piping Handling Flammable Liquids or Gases

Process Equipment	Units	Small/Low	Moderate	Large/ High
Size	gal	<5000	5000 to 25000	>25000
Pressure	psi	< 100	100 to 500	> 500
Flow Rate	gpm	< 100	100 to 500	> 500

3-3 Procedure for Classifying Locations.

The following procedure should be used for each room, section, or area being classified.

3-3.1 Step One — Need for Classification.

The area should be classified if the answer to either of the following questions is "Yes":

(a) Are flammable liquids or flammable gases likely to be present?

(b) Are combustible liquids likely to be handled, processed, or stored at temperatures above their flash points?

3-3.2 Step Two — Assignment of Division Classification.

Assuming an affirmative answer to Step One, the following questions should be answered to determine the correct Division classification.

3-3.2.1 Division 1 locations are distinguished by a "Yes" answer to any one of the following questions:

(a) Is an ignitible atmospheric mixture likely to exist under normal operating conditions?

(b) Is an ignitible atmospheric mixture likely to occur frequently due to repair, maintenance, or leakage?

(c) Would failure of process equipment, storage vessels, or piping systems be likely to cause a failure of the electrical system simultaneous with the release of the combustible material?

(d) Is a piping system containing a combustible material in an inadequately ventilated space, and is the piping system likely to leak?

(e) Is the space or area in question below grade level such that vapors may accumulate there?

(f) Are pressure relief valve discharges located within the area?

3-3.2.2 Division 2 locations are distinguished by a "Yes" answer to any of the following questions:

(a) Is a piping system containing a combustible material in an inadequately ventilated space, and is the piping system *not* likely to leak?

(b) Is a process equipment system containing a combustible material in an inadequately ventilated space, and can the material escape only during abnormal situations, such as failure of a gasket or packing?

(c) Is the location adjacent and open to a Division 1 location, or can gas or vapor be transmitted from a Division 1 location to the location in question by trenches, pipes, or ducts?

(d) If mechanical ventilation is used, can failure or abnormal operation of the ventilation equipment permit an ignitible atmospheric mixture?

3-3.3 Step Three — Extent of Classified Location.

The extent of the classified location may be determined by applying, with sound engineering judgment, the distances recommended in the diagrams contained in this chapter.

3-4 Index of Classification Diagrams.

This section contains descriptions of the classification diagrams that follow. Most of the diagrams include a table of "suggested applicability," corresponding to Table 3-2. The check marks show the ranges of process equipment size, pressure, and flow rate where each diagram most appropriately applies. Unless otherwise stated, these diagrams assume that the material being handled is a flammable liquid.

Figure 3-4.1 shows a source of leakage located outdoors, at grade. The material being handled is a flammable liquid.

Figure 3-4.2 shows a source of leakage located outdoors, above grade. The material being handled is a flammable liquid.

Figure 3-4.3 shows a source of leakage located indoors, at floor level. Adequate ventilation is provided. The material being handled is a flammable liquid.

Figure 3-4.4 shows a source of leakage located indoors, above floor level. Adequate ventilation is provided. The material being handled is a flammable liquid.

Figure 3-4.5 shows a source of leakage located indoors, at floor level, adjacent to an opening in an exterior wall. Adequate ventilation is provided. The material being handled is a flammable liquid.

Figure 3-4.6 shows a source of leakage located indoors, at floor level, adjacent to an opening in an exterior wall. Ventilation is *not* adequate. The material being handled is a flammable liquid.

Figure 3-4.7 shows a source of leakage located outdoors, at grade. The material being handled may be a flammable liquid or a liquefied or compressed flammable gas, or a flammable cryogenic liquid.

Figure 3-4.8 shows a source of leakage located outdoors, above grade. The material being handled may be a flammable liquid or a liquefied or compressed flammable gas, or a flammable cryogenic liquid.

Figure 3-4.9 shows a source of leakage located outdoors, at grade. The material being handled is a flammable liquid.

Figure 3-4.10 shows a source of leakage located outdoors, above grade. The material being handled is a flammable liquid.

Figure 3-4.11 shows a source of leakage located indoors, adjacent to an opening in an exterior wall. Ventilation is *not* adequate. The material being handled is a flammable liquid.

Figure 3-4.12 shows a source of leakage located indoors, adjacent to an opening in an exterior wall. Adequate ventilation is provided. The material being handled is a flammable liquid.

Figure 3-4.13 shows multiple sources of leakage, located both at grade and above grade, in an outdoor process area. The material being handled is a flammable liquid.

Figure 3-4.14 shows multiple sources of leakage, located both at grade and above grade, in an outdoor process area. The material being handled is a flammable liquid.

Figure 3-4.15 shows multiple sources of leakage, located both at and above grade, in an outdoor process area. The material being handled is a flammable liquid.

Figure 3-4.16 shows multiple sources of leakage, located both at and above floor level, in an adequately ventilated building. The material being handled is a flammable liquid.

Figure 3-4.17 shows a product dryer located in an adequately ventilated building. The product dryer system is totally enclosed. The material being handled is a solid wet with a flammable liquid.

Figure 3-4.18 shows a plate and frame filter press. Adequate ventilation is provided. The material being handled is a solid wet with a flammable liquid.

Figure 3-4.19 shows a product storage tank located outdoors, at grade. The material being stored is a flammable liquid.

Figure 3-4.20 shows tank car loading and unloading via a closed transfer system. Material is transferred only through the dome. The material being transferred is a flammable liquid.

Figures 3-4.21(a) and (b) show tank car and tank truck loading and unloading via a closed transfer system. Material is transferred through the bottom fittings. The material being transferred is a flammable liquid.

Figure 3-4.22 shows tank car (or tank truck) loading and unloading via an open transfer system. Material is transferred either through the dome or the bottom fittings. The material being transferred is a flammable liquid.

Figure 3-4.23 shows tank car (or tank truck) loading and unloading via a closed transfer system. Material is transferred only through the dome. The material being transferred may be a liquefied or compressed flammable gas or a flammable cryogenic liquid.

Figure 3-4.24 shows a drum filling station located either outdoors or indoors in an adequately ventilated building. The material being handled is a flammable liquid.

Figure 3-4.25 shows an emergency impounding basin or oil/water separator and an emergency or temporary drainage ditch oil/water separator. The material being handled is a flammable liquid.

Figure 3-4.26 shows a liquid hydrogen storage located outdoors or indoors in an adequately ventilated building. This diagram applies to liquid hydrogen only.

Figure 3-4.27 shows a gaseous hydrogen storage located outdoors or indoors in an adequately ventilated building. This diagram applies to gaseous hydrogen only.

Figure 3-4.28 shows an adequately ventilated compressor shelter. The material being handled is a lighter-than-air gas.

Figure 3-4.29 shows an inadequately ventilated compressor shelter. The material being handled is a lighter-than-air gas.

Figure 3-4.30 shows tanks for the storage of cryogenic and other cold liquefied flammable gases. [From NFPA 59A, *Standard for the Production, Storage, and Handling of Liquefied Natural Gas (LNG)*.]

Figure 3-4.31 shows a source of leakage from equipment handling liquefied natural gas or other cold liquefied flammable gas, and located outdoors, at or above grade. [From NFPA 59A, *Standard for the Production, Storage, and Handling of Liquefied Natural Gas (LNG).*]

Figure 3-4.32 shows a source of leakage from equipment handling liquefied natural gas or other cold liquefied flammable gas and located indoors in an adequately ventilated building. [From NFPA 59A, *Standard for the Production, Storage, and Handling of Liquefied Natural Gas (LNG).*]

Figure 3-4.33 shows the classified zones around liquefied natural gas operating bleeds, drips, vents, and drains both outdoors, at or above grade, and indoors in an adequately ventilated building. This diagram also applies to other cold liquefied flammable gases. [From NFPA 59A, *Standard for the Production, Storage, and Handling of Liquefied Natural Gas (LNG).*]

Figure 3-4.34 shows the classified zones at a marine terminal handling flammable liquids and includes the area around the stored position of loading arms and hoses.

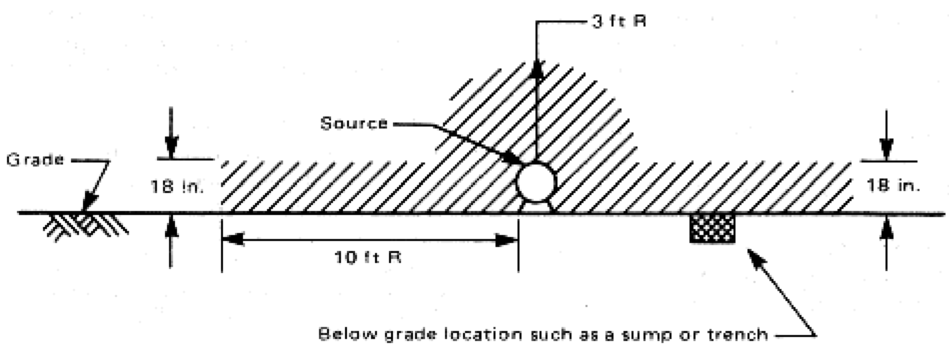


Figure 3-4.1 Leakage source located outdoors, at grade.

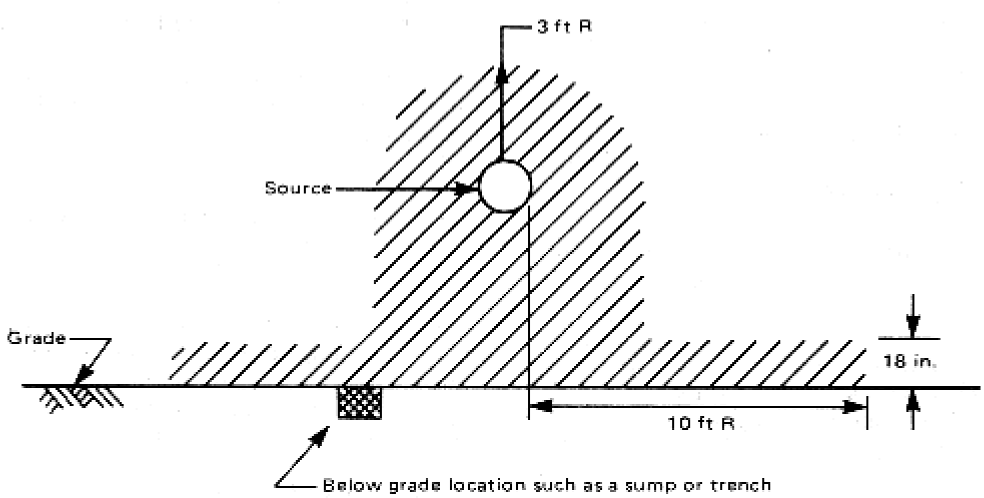


Figure 3-4.2 Leakage source located outdoors, above grade.

Material: Flammable Liquid

	Small/ Low	Moderate	Large/ High
Process Equip. Size	√	√	
Pressure	√	√	
Flow Rate	√	√	

Division 1

Division 2

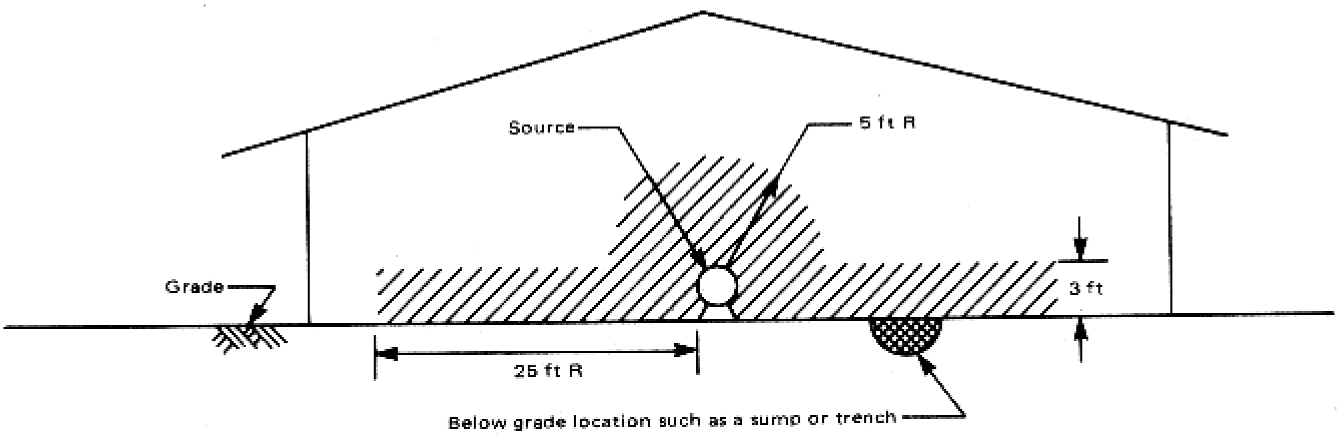


Figure 3-4.3 Leakage source located indoors, at floor level. Adequate ventilation is provided.

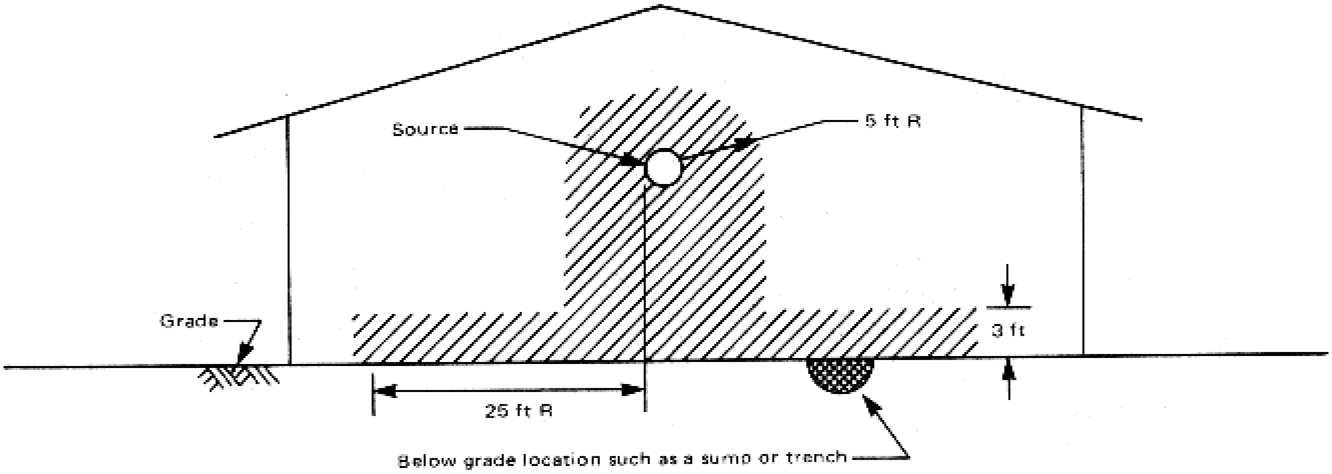


Figure 3-4.4 Leakage source located indoors, above floor level. Adequate ventilation is provided.

Material: Flammable Liquid

	Small/ Low	Moderate	Large/ High
Process Equip. Size	√	√	
Pressure	√	√	
Flow Rate	√	√	

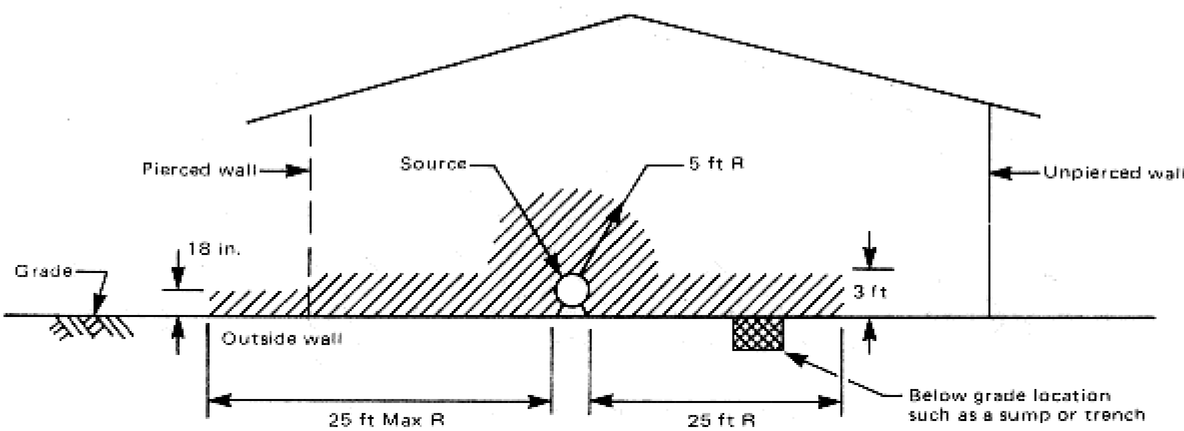


Figure 3-4.5 Leakage source located indoors, at floor level, adjacent to opening in exterior wall. Adequate ventilation is provided.

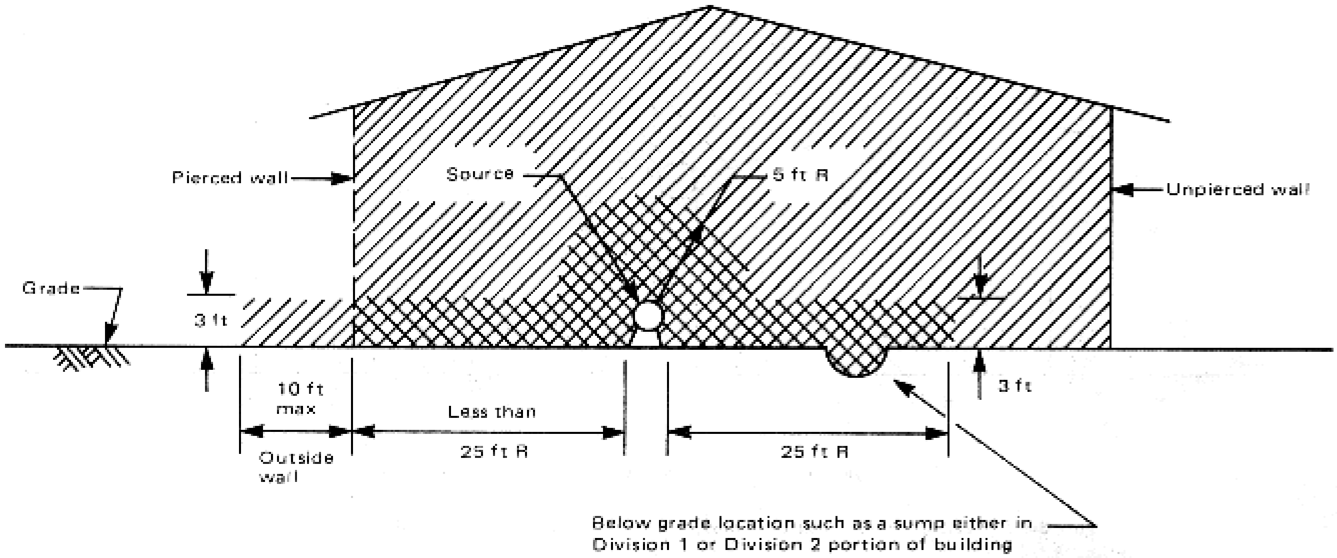


Figure 3-4.6 Leakage source located indoors, at floor level, adjacent to opening in exterior wall. Adequate ventilation is not provided.

NOTE: If building is small compared to size of equipment and leakage can fill the building, the entire building interior is classified Division 1.

Material: Flammable Liquid

	Small/ Low	Moderate	Large/ High
Process Equip. Size	√	√	
Pressure	√	√	
Flow Rate	√	√	

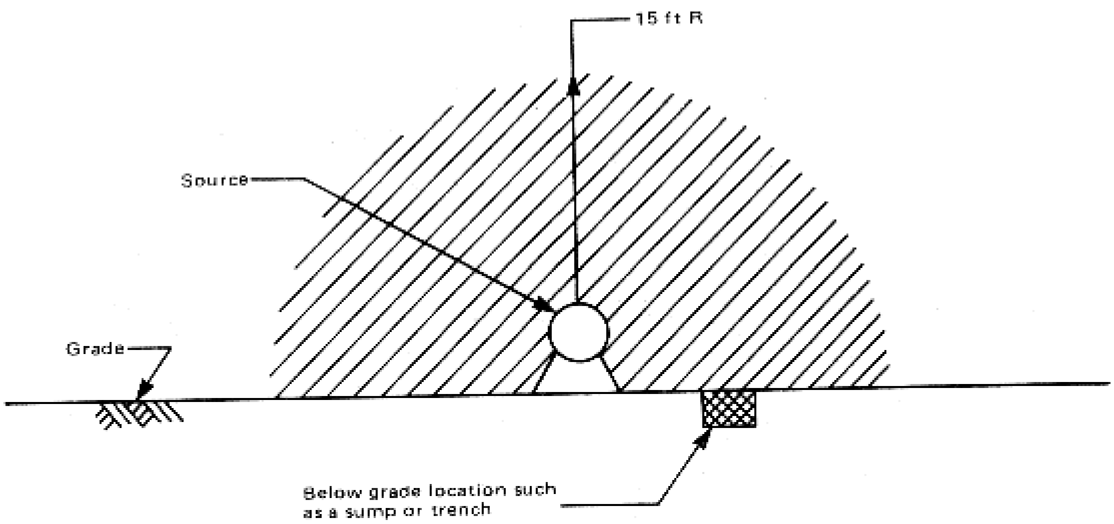


Figure 3-4.7 Leakage source located outdoors, at grade.

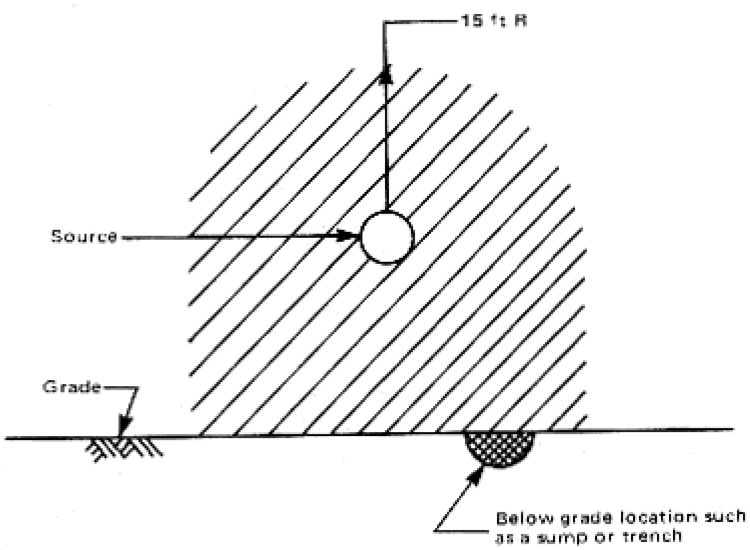
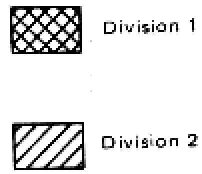


Figure 3-4.8 Leakage source located outdoors, above grade.

Material: Flammable Liquid, Liquefied Flammable Gas, Compressed Flammable Gas, and Cryogenic Liquid

	Small/ Low	Moderate	Large/ High
Process Equip. Size	√	√	
Pressure		√	√
Flow Rate	√	√	



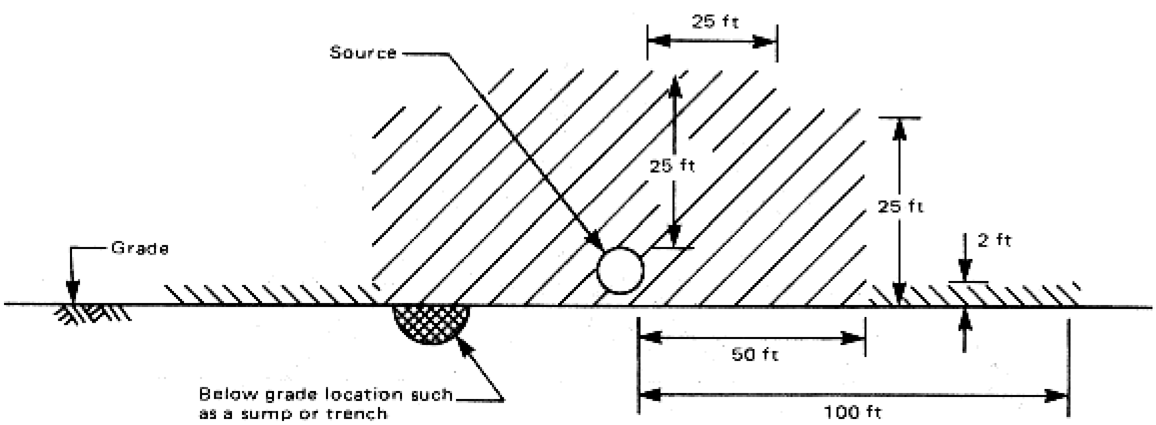


Figure 3-4.9 Leakage source located outdoors, at grade.

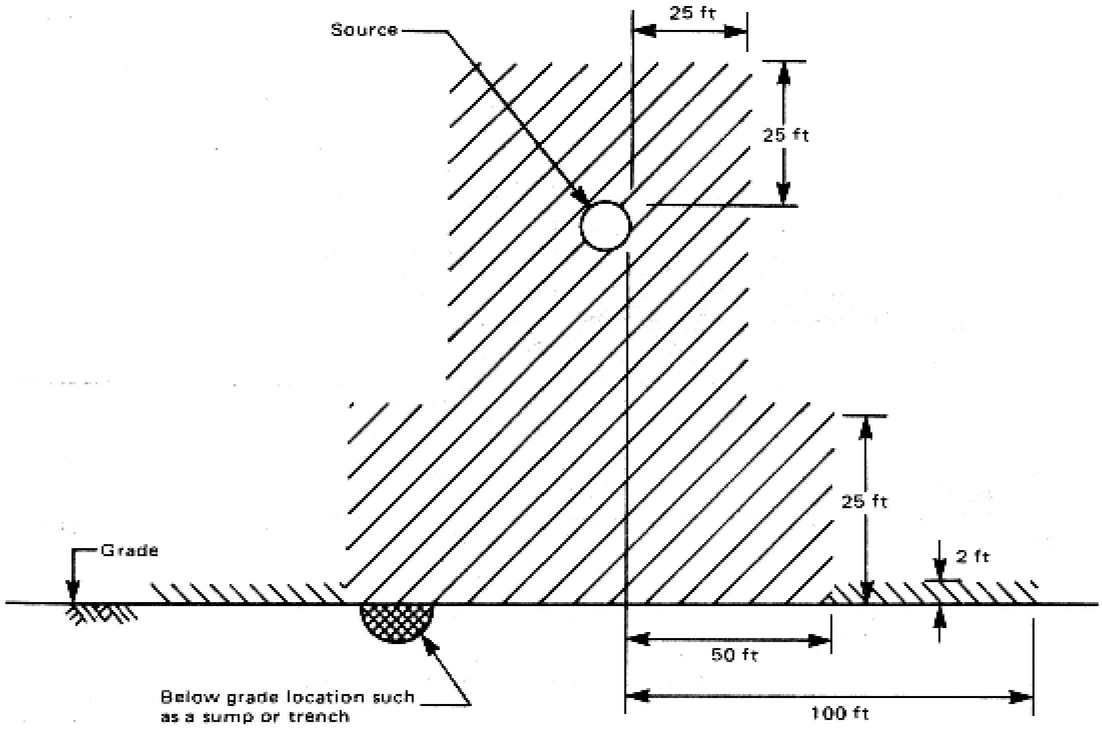
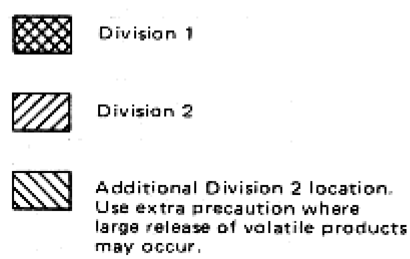
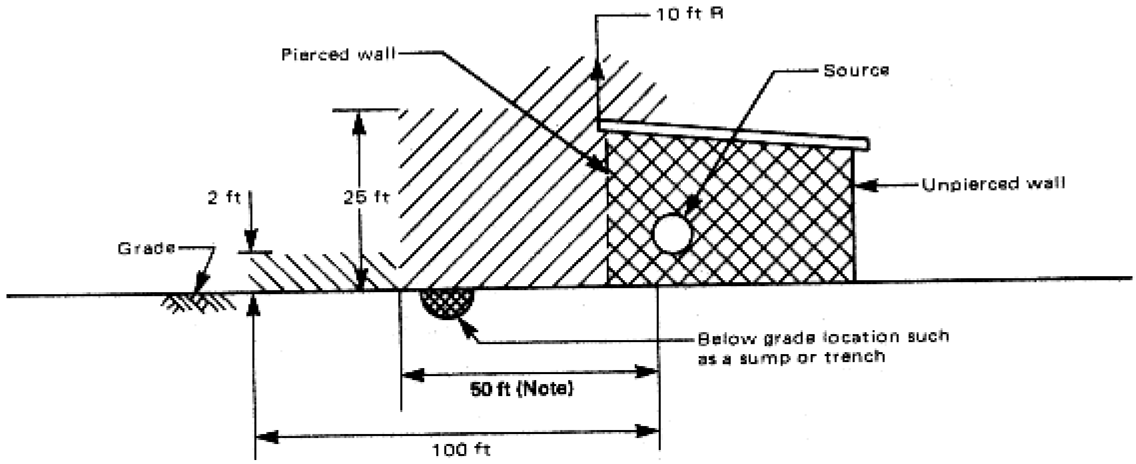


Figure 3-4.10 Leakage source located outdoors, above grade.

Material: Flammable Liquid

	Small/ Low	Moderate	Large/ High
Process Equip. Size			√
Pressure		√	√
Flow Rate			√





NOTE: "Apply" horizontal distances of 50 feet from the source of vapor or 10 feet beyond the perimeter of the building, whichever is greater, except that beyond unpierced vaportight walls the area is nonclassified.

Figure 3-4.11 Leakage source located indoors, adjacent to opening in exterior wall. Adequate ventilation is not provided.

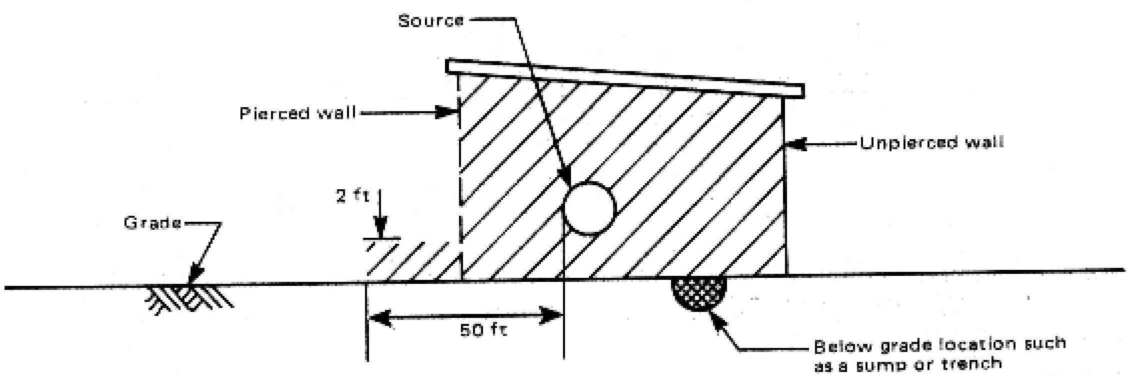


Figure 3-4.12 Leakage source located indoors, adjacent to opening in exterior wall. Adequate ventilation is provided.

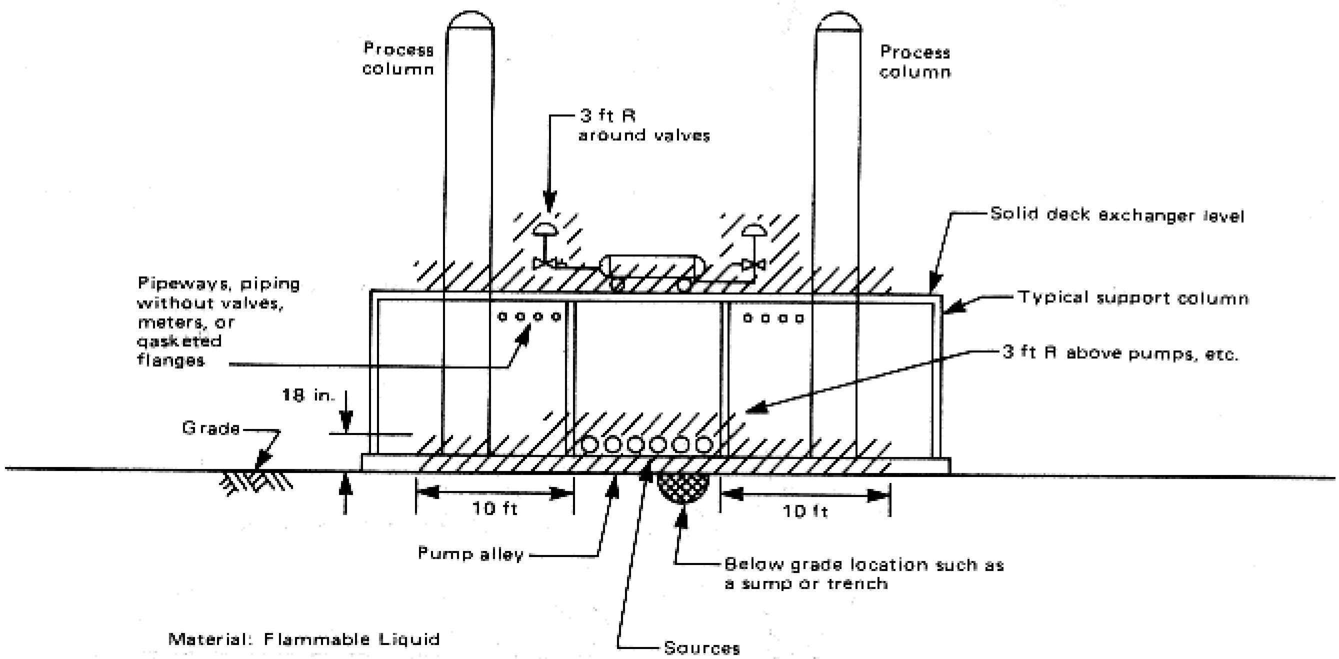
Material: Flammable Liquid

	Small/ Low	Moderate	Large/ High
Process Equip. Size		√	√
Pressure			√
Flow Rate		√	√

Division 1

Division 2

Additional Division 2 location. Use extra precaution where large release of volatile products may occur.



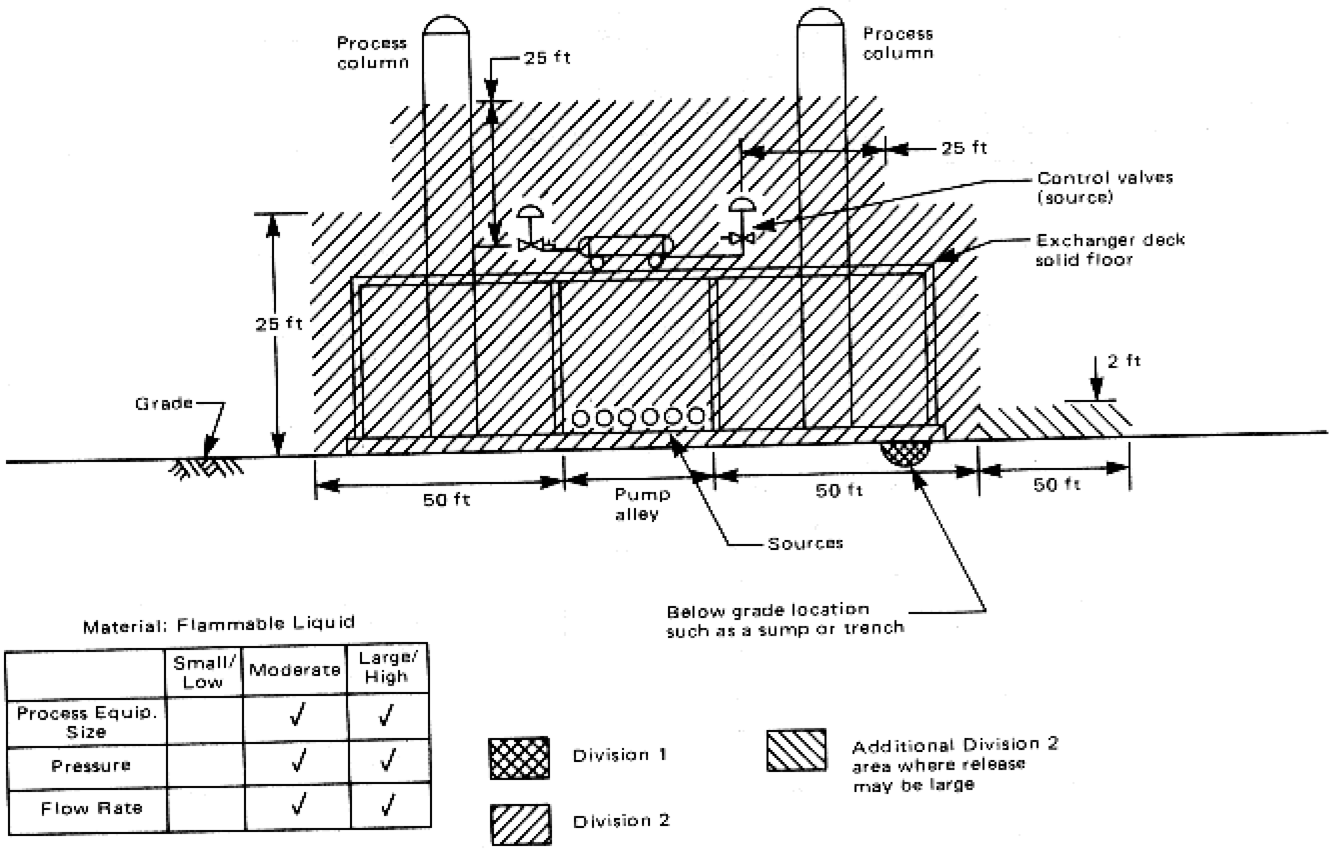
Material: Flammable Liquid

	Small/ Low	Moderate	Large/ High
Process Equip. Size	√	√	
Pressure	√	√	
Flow Rate	√	√	

Division 1

Division 2

Figure 3-4.13 Multiple leakage sources, both at and above grade, in outdoor process area.



Material: Flammable Liquid

	Small/ Low	Moderate	Large/ High
Process Equip. Size		√	√
Pressure		√	√
Flow Rate		√	√

Figure 3-4.14 Multiple leakage sources, both at and above grade, in outdoor process area.

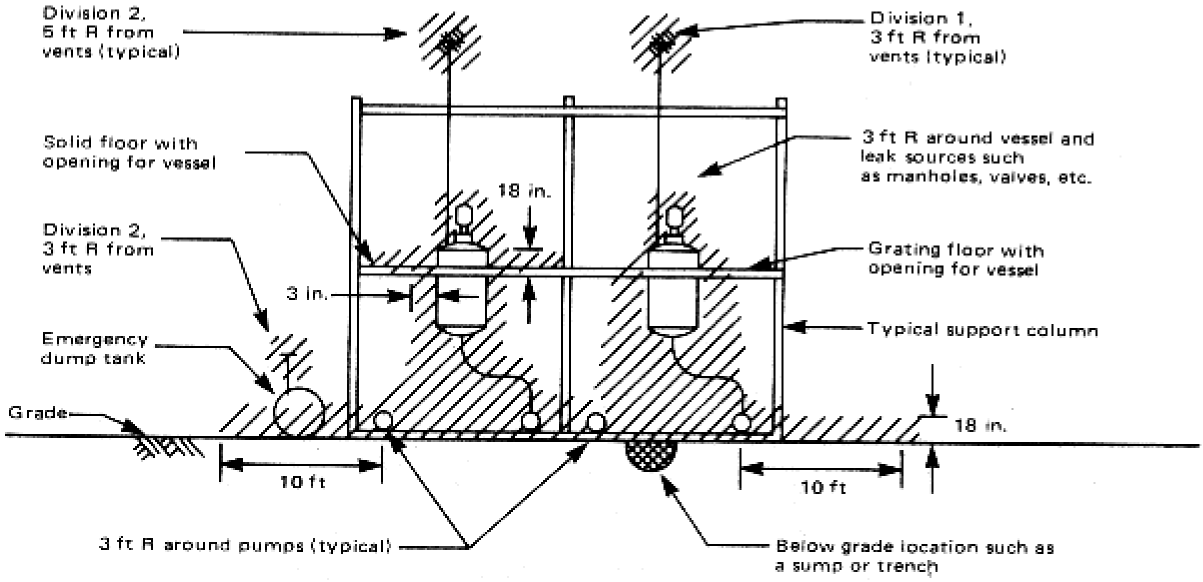
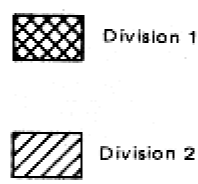


Figure 3-4.15 Multiple leakage sources, both at and above grade, in outdoor process area.

Material: Flammable Liquid

	Small/ Low	Moderate	Large/ High
Process Equip. Size	√	√	
Pressure	√	√	
Flow Rate	√	√	



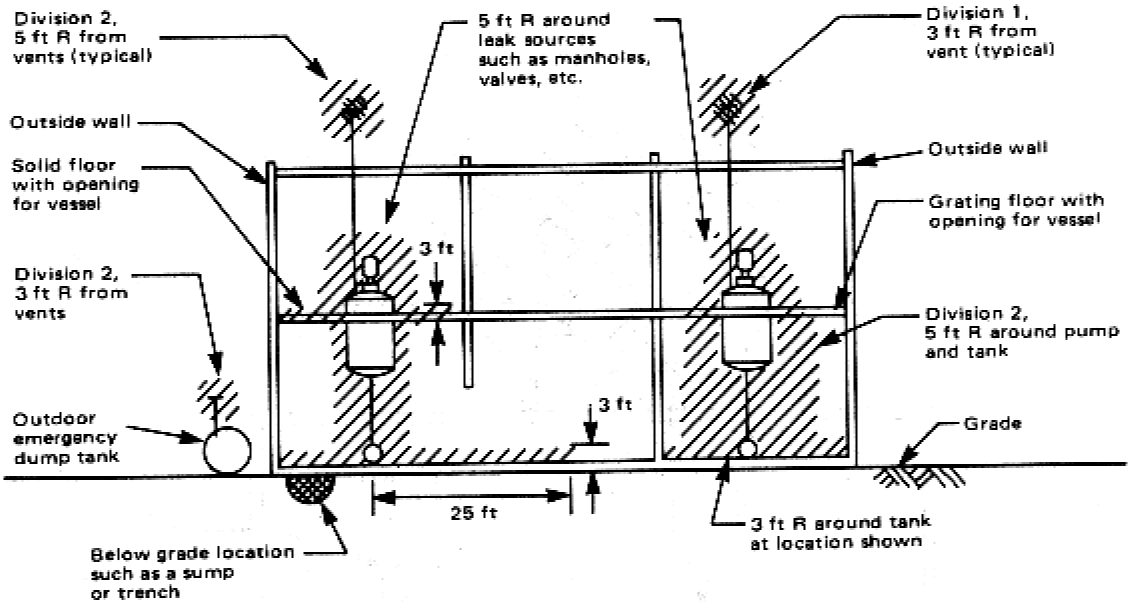


Figure 3-4.16 Multiple leakage sources, both at and above floor level, located indoors. Adequate ventilation is provided.

Material: Flammable Liquid

	Small/ Low	Moderate	Large/ High
Process Equip. Size	√	√	
Pressure	√	√	
Flow Rate	√	√	

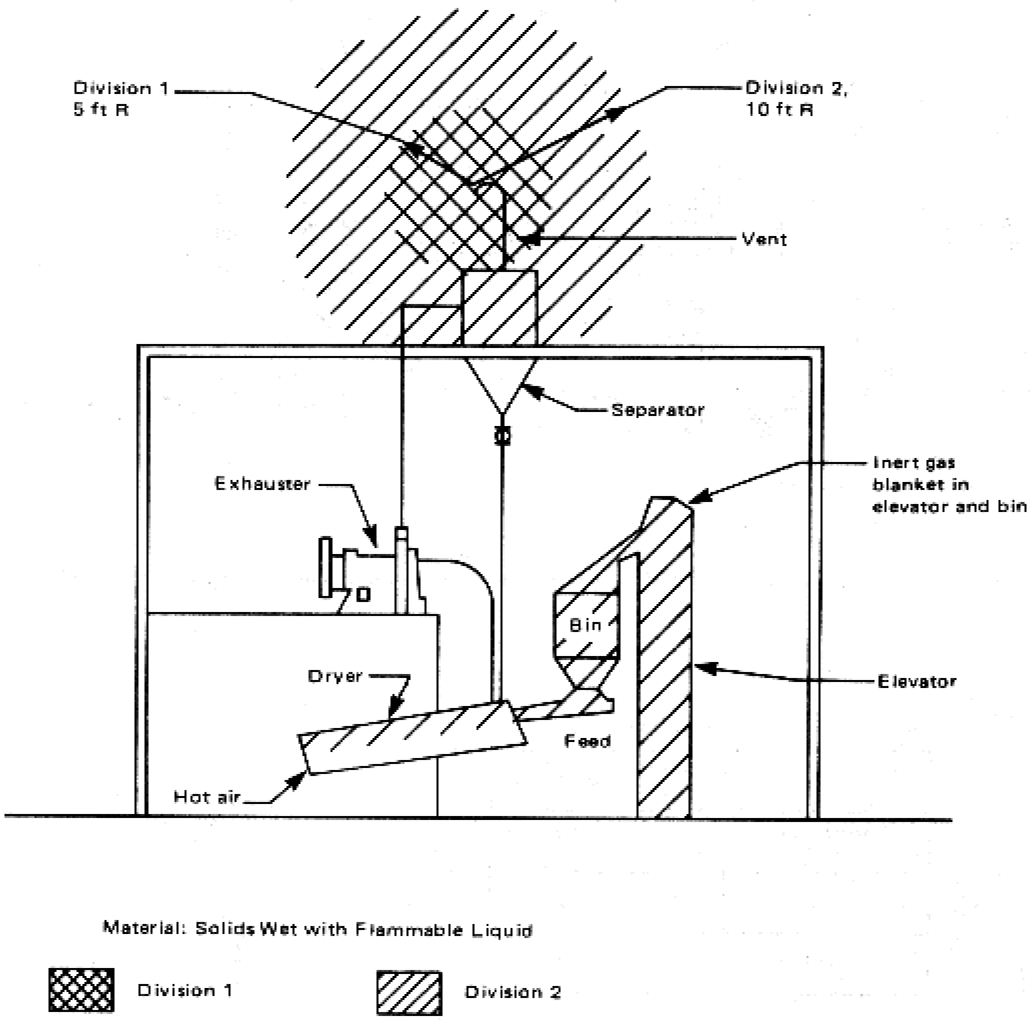


Figure 3-4.17 Totally enclosed product dryer located in adequately ventilated building.

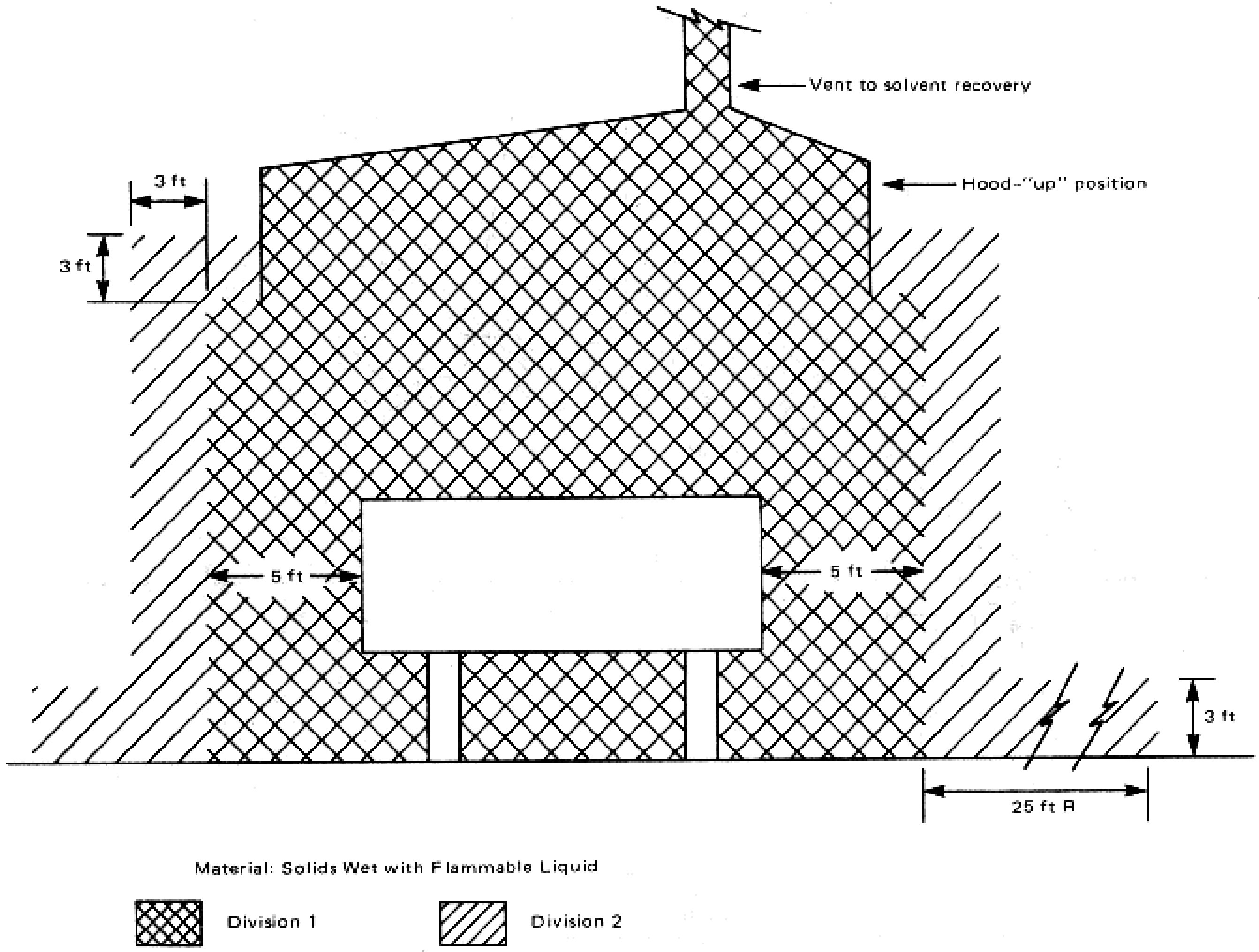
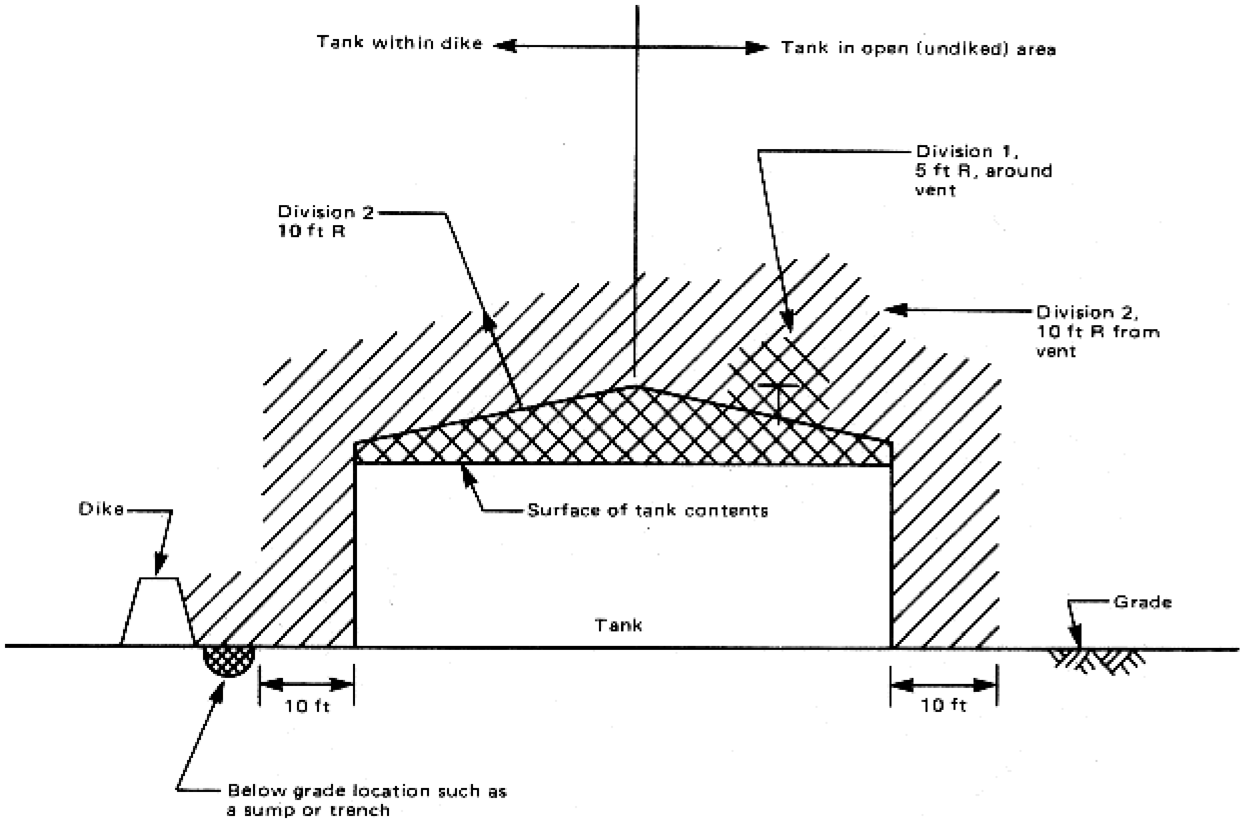


Figure 3-4.18 Plate and frame filter press provided with adequate ventilation.



Material: Flammable Liquid

	Small/ Low	Moderate	Large/ High
Process Equip. Size		√	√
Pressure			√
Flow Rate		√	√

Division 1

Division 2

Figure 3-4.19 Storage tanks, outdoors at grade.

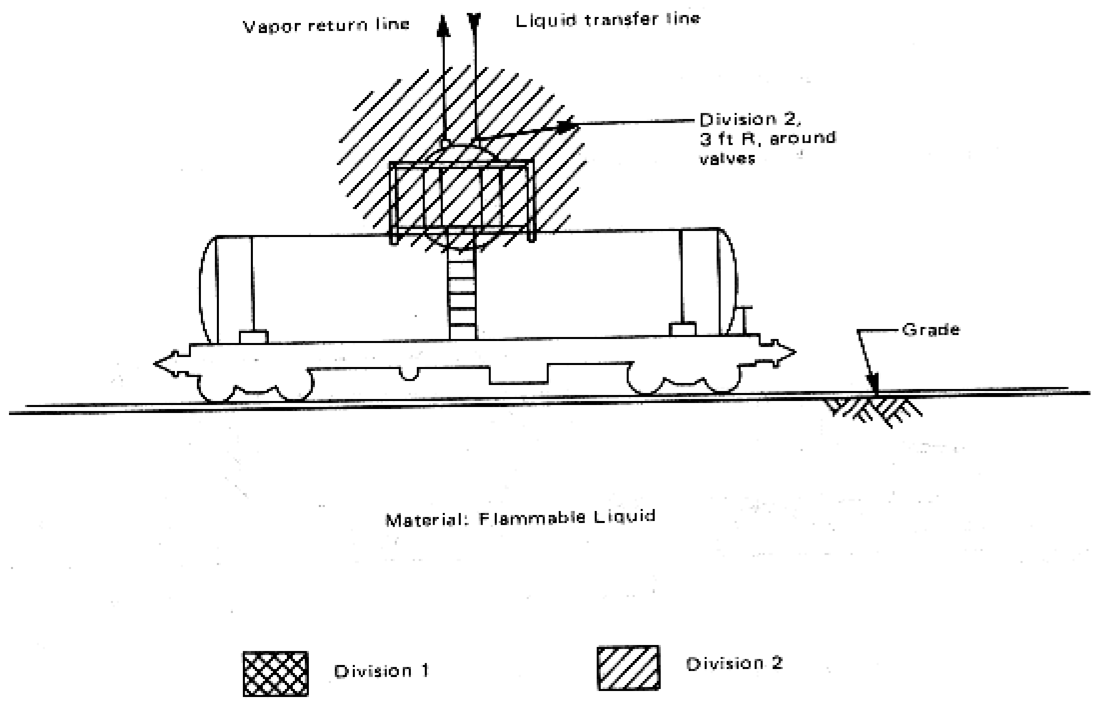


Figure 3-4.20 Tank car/tank loading and unloading via closed system. Transfer through dome only.

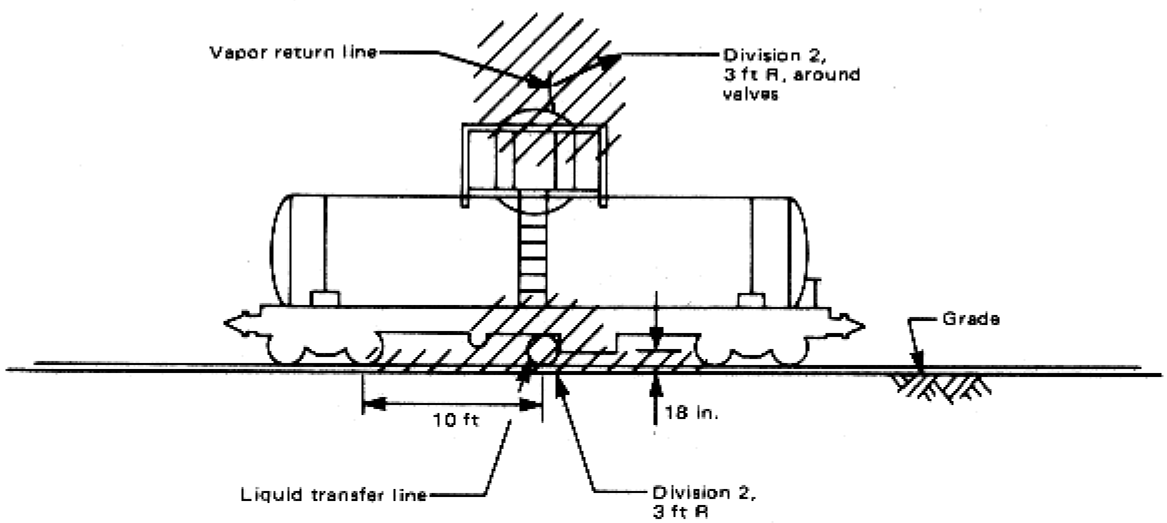


Figure 3-4.21(a) Tank car loading and unloading via closed system. Bottom product transfer only.

MATERIAL: Flammable Liquid

MATERIAL: Flammable Liquid

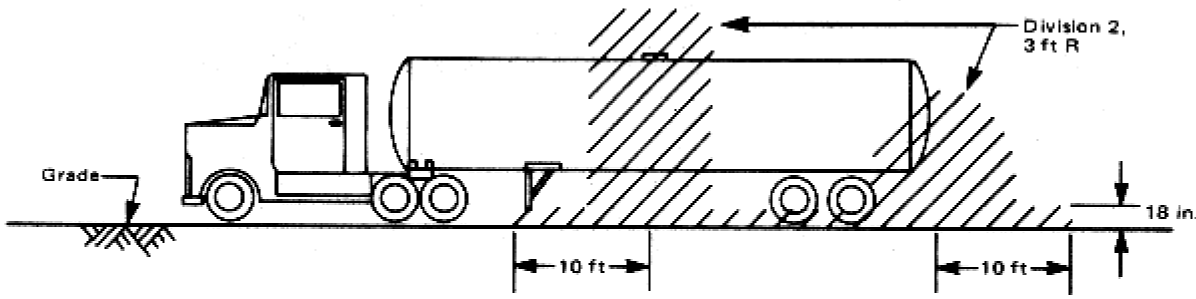


Figure 3-4.21(b) Tank truck loading and unloading via closed system.

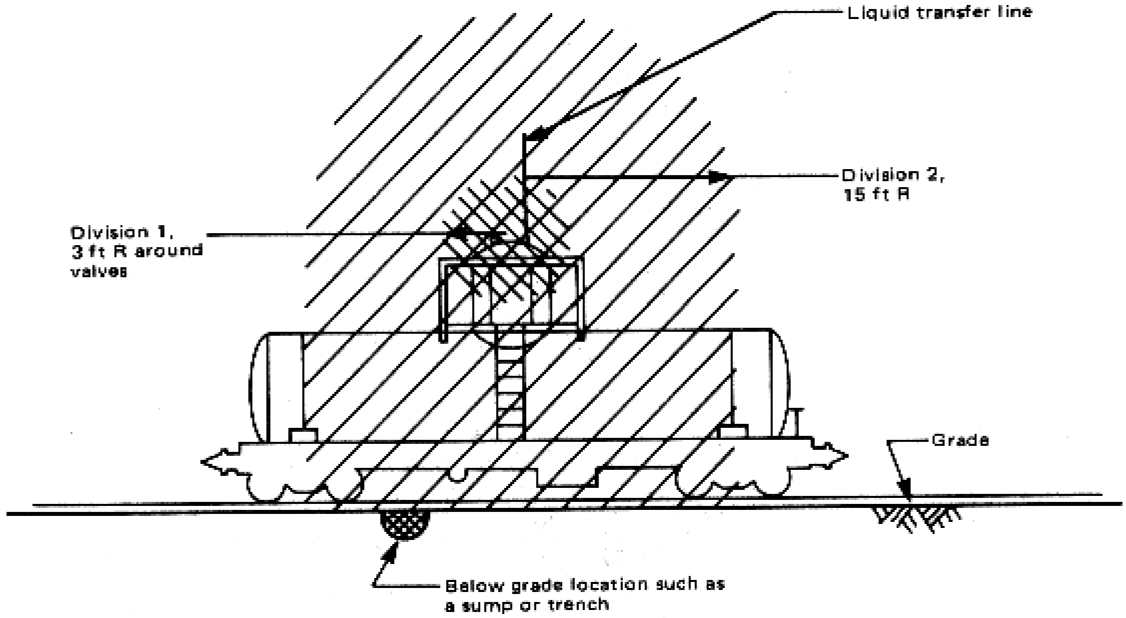


Figure 3-4.22 Tank car/tank truck loading and unloading via open system. Top or bottom product transfer.

MATERIAL: Flammable Liquid

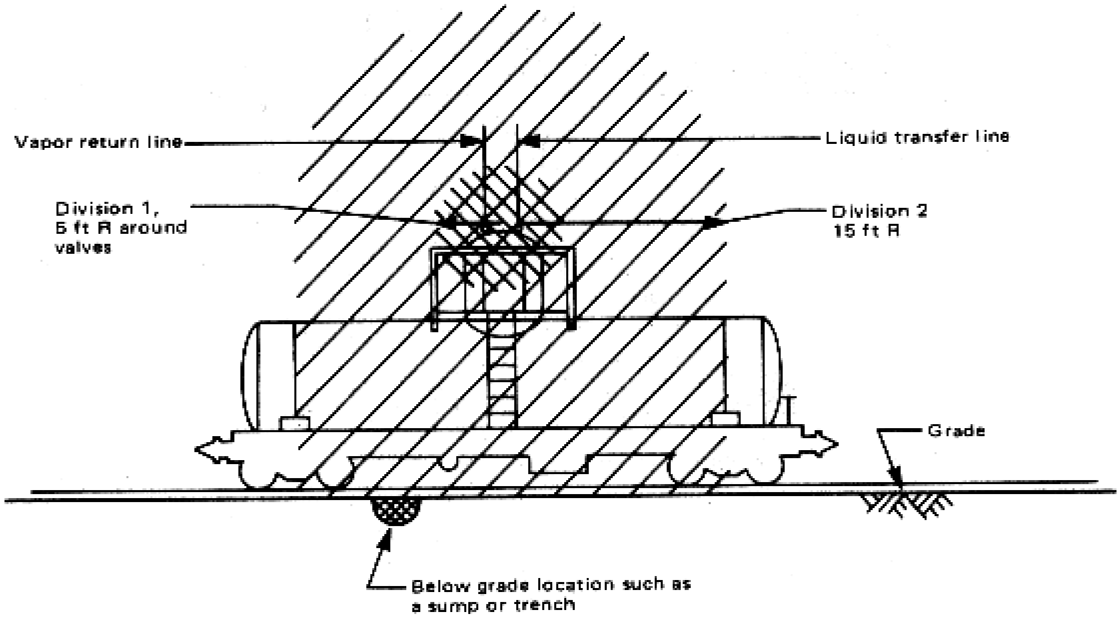


Figure 3-4.23 Tank car/tank truck loading and unloading via closed system. Transfer through dome only.

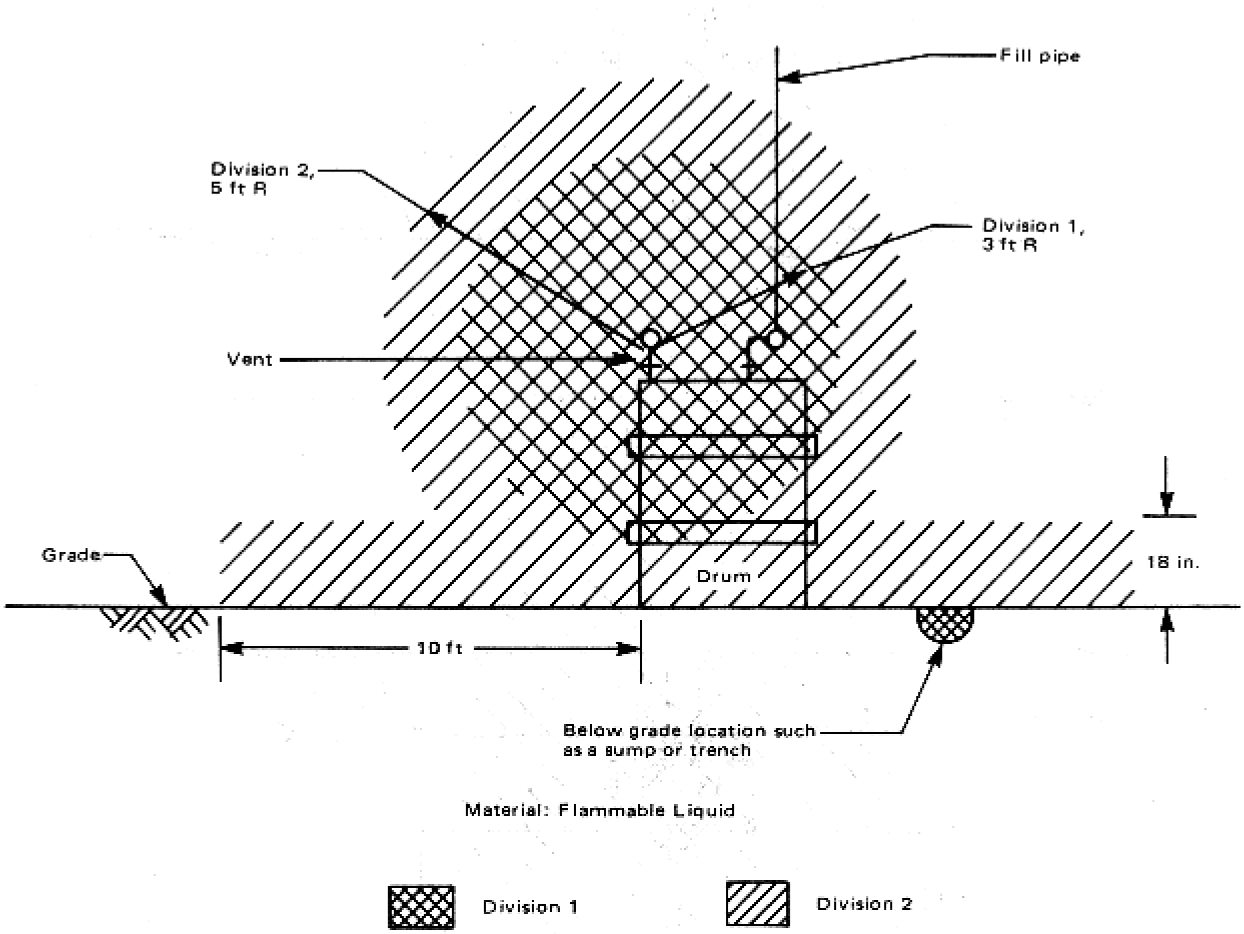
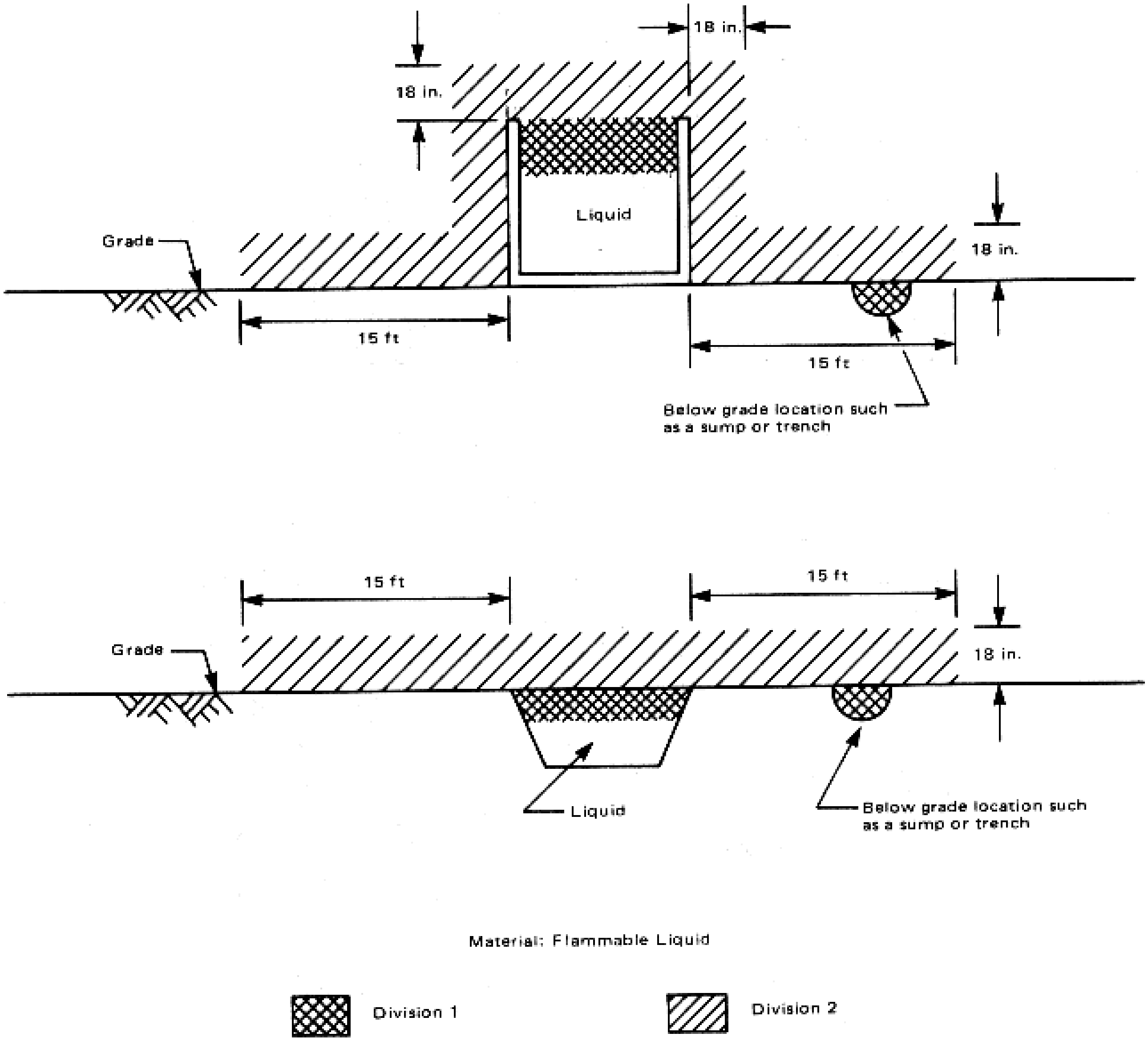


Figure 3-4.24 Drum filling station, outdoors or indoors, with adequate ventilation.



NOTE: This diagram does not apply to open pits or open vessels, such as dip tanks or open mixing tanks, that normally contain flammable liquids.

Figure 3-4.25 Emergency impounding basin or oil/water separator (top) and emergency or drainage ditch oil/water separator (bottom).

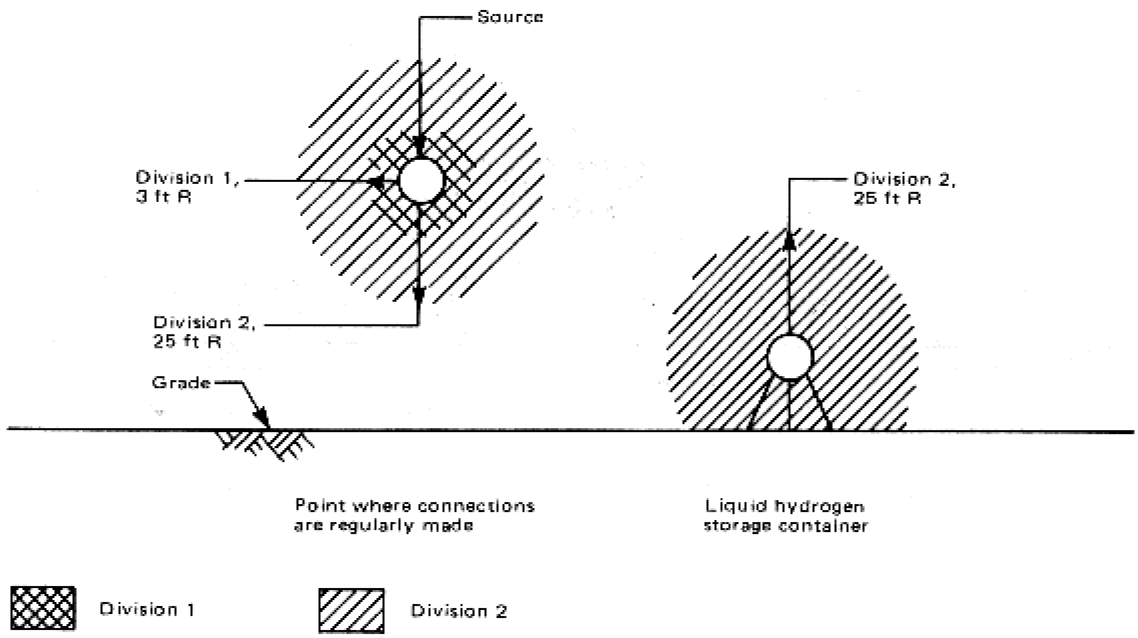


Figure 3-4.26 Liquid hydrogen storage located outdoors or in an adequately ventilated building.

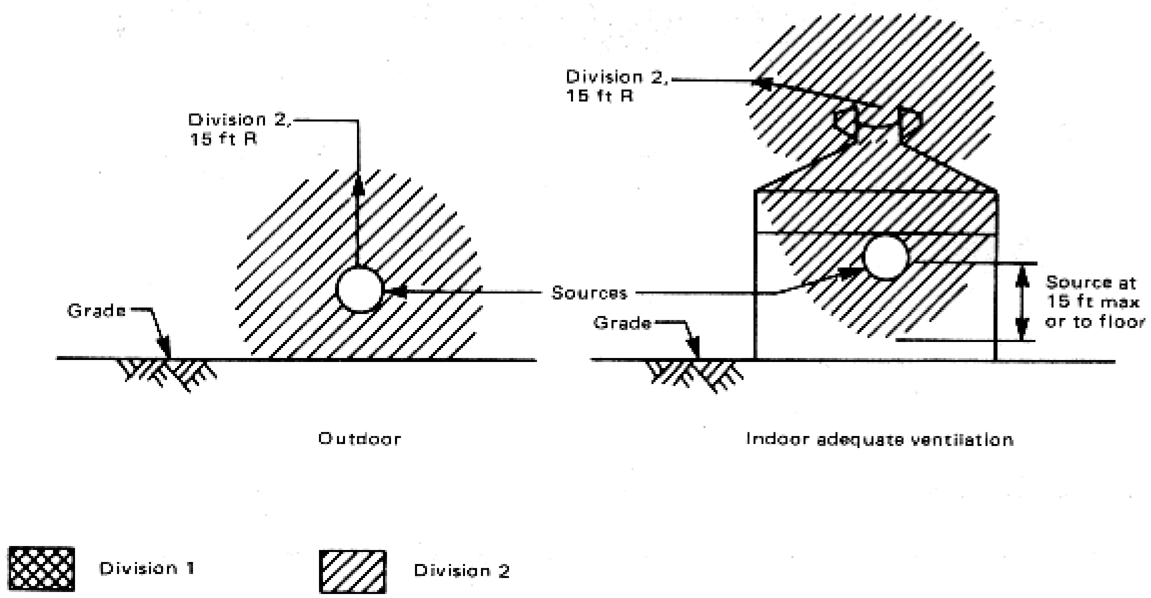


Figure 3-4.27 Gaseous hydrogen storage located outdoors or indoors in an adequately ventilated building.

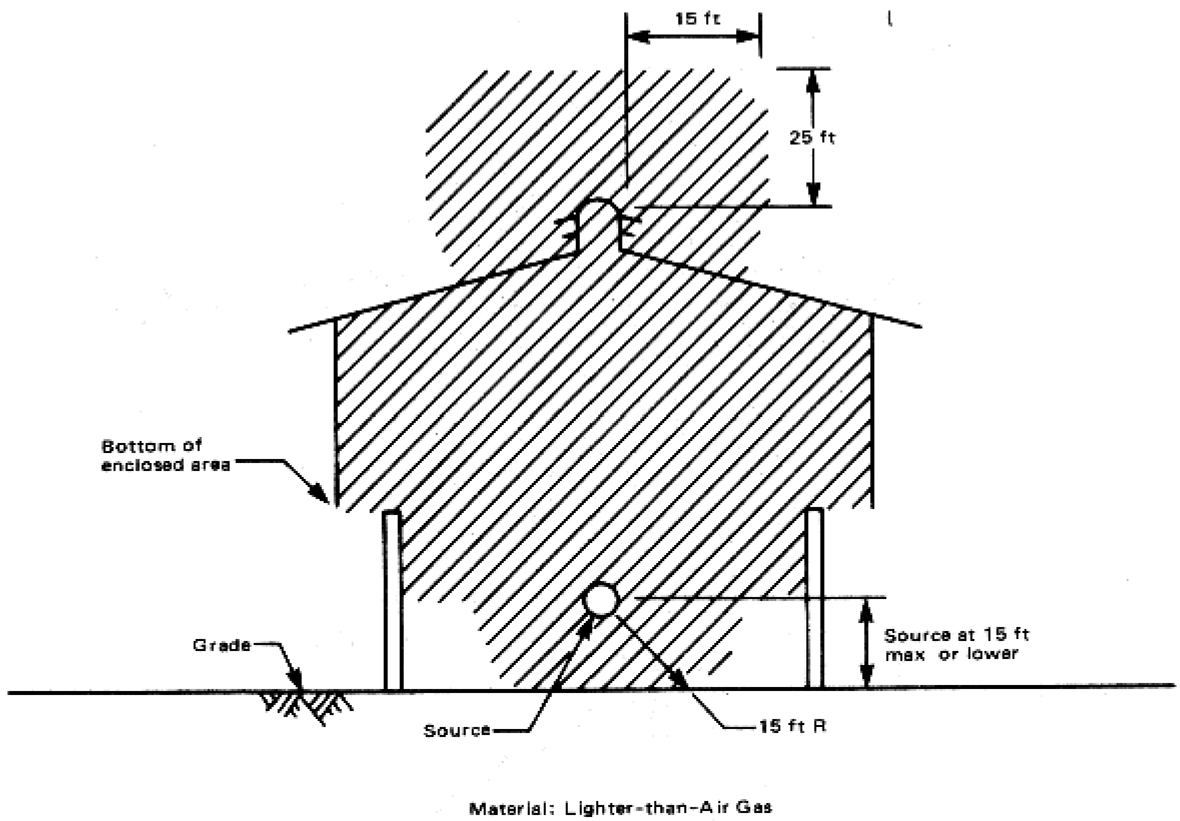


Figure 3-4.28 Adequately ventilated compressor shelter.

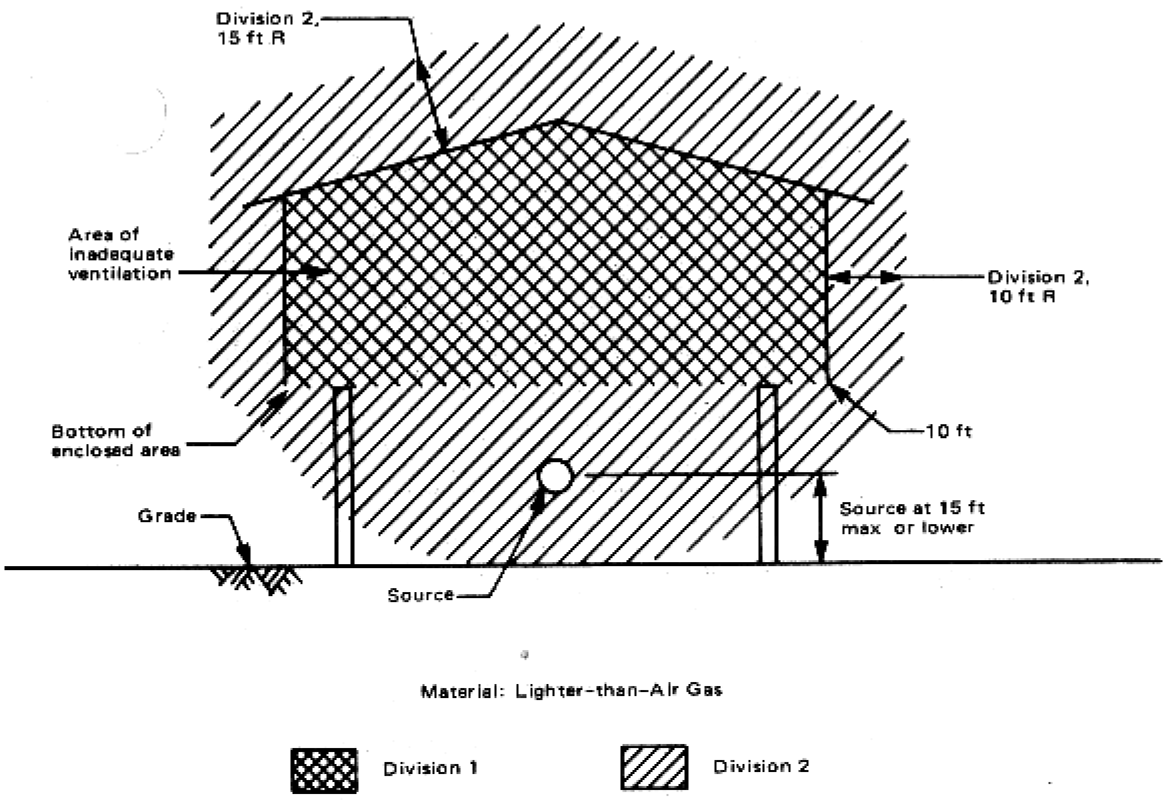
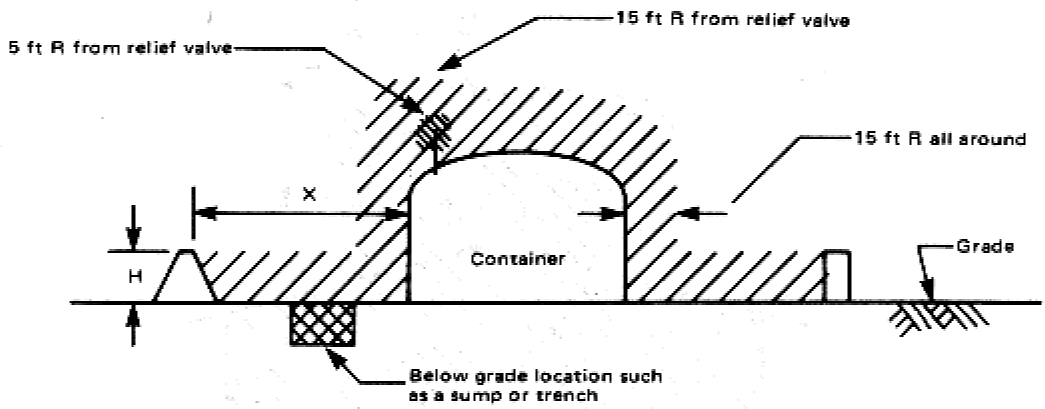
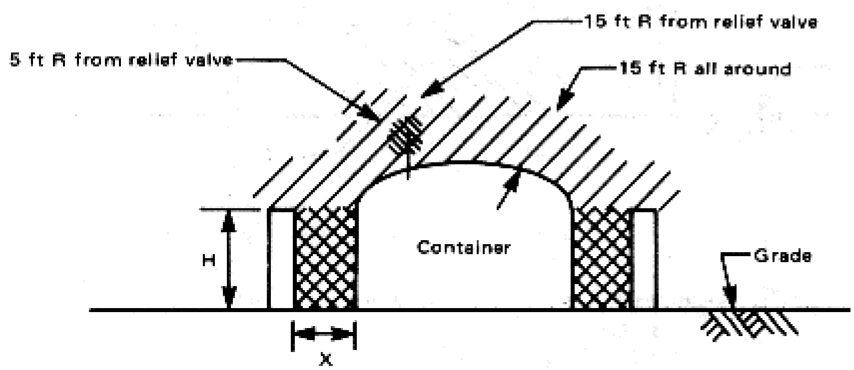


Figure 3-4.29 Inadequately ventilated compressor shelter.



Dike height less than distance from container to dike (H less than X)



Dike height greater than distance from container to dike (H greater than X)

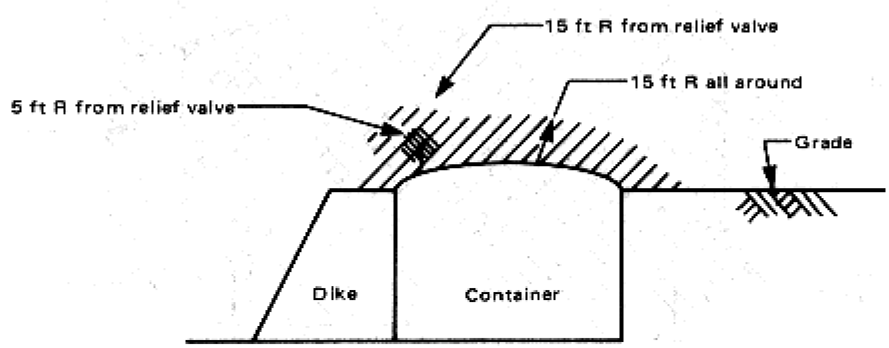


Figure 3-4.30 Storage tanks for cryogenic liquids.

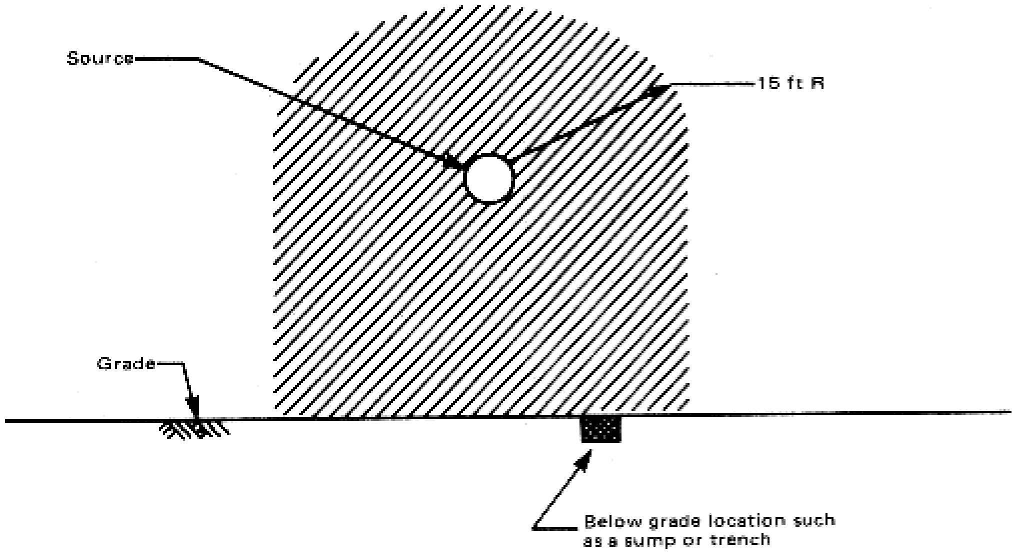


Figure 3-4.31 Leakage source from equipment handling liquefied natural gas. Source is located outdoors at or above grade.

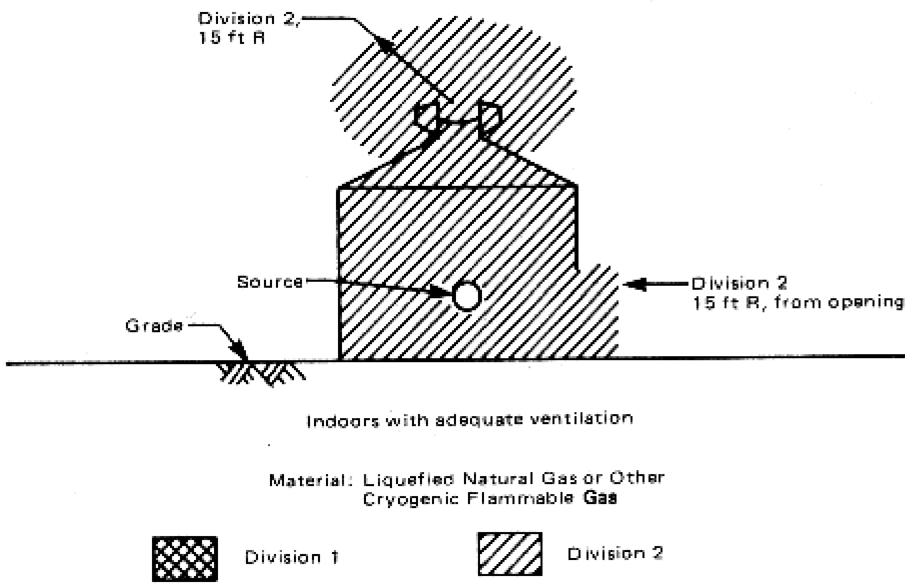


Figure 3-4.32 Leakage source from equipment handling liquefied natural gas in an adequately ventilated building.

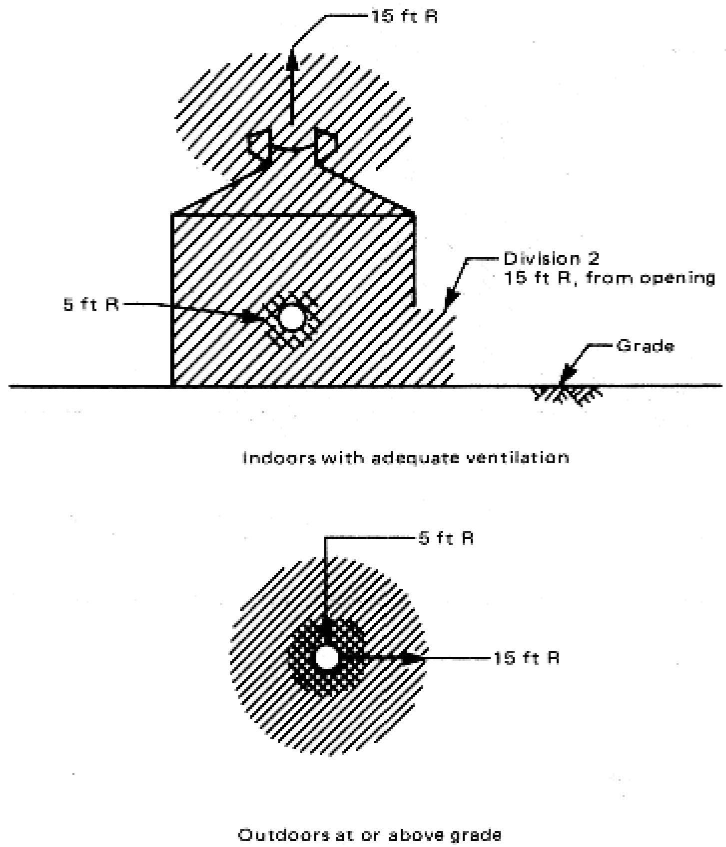
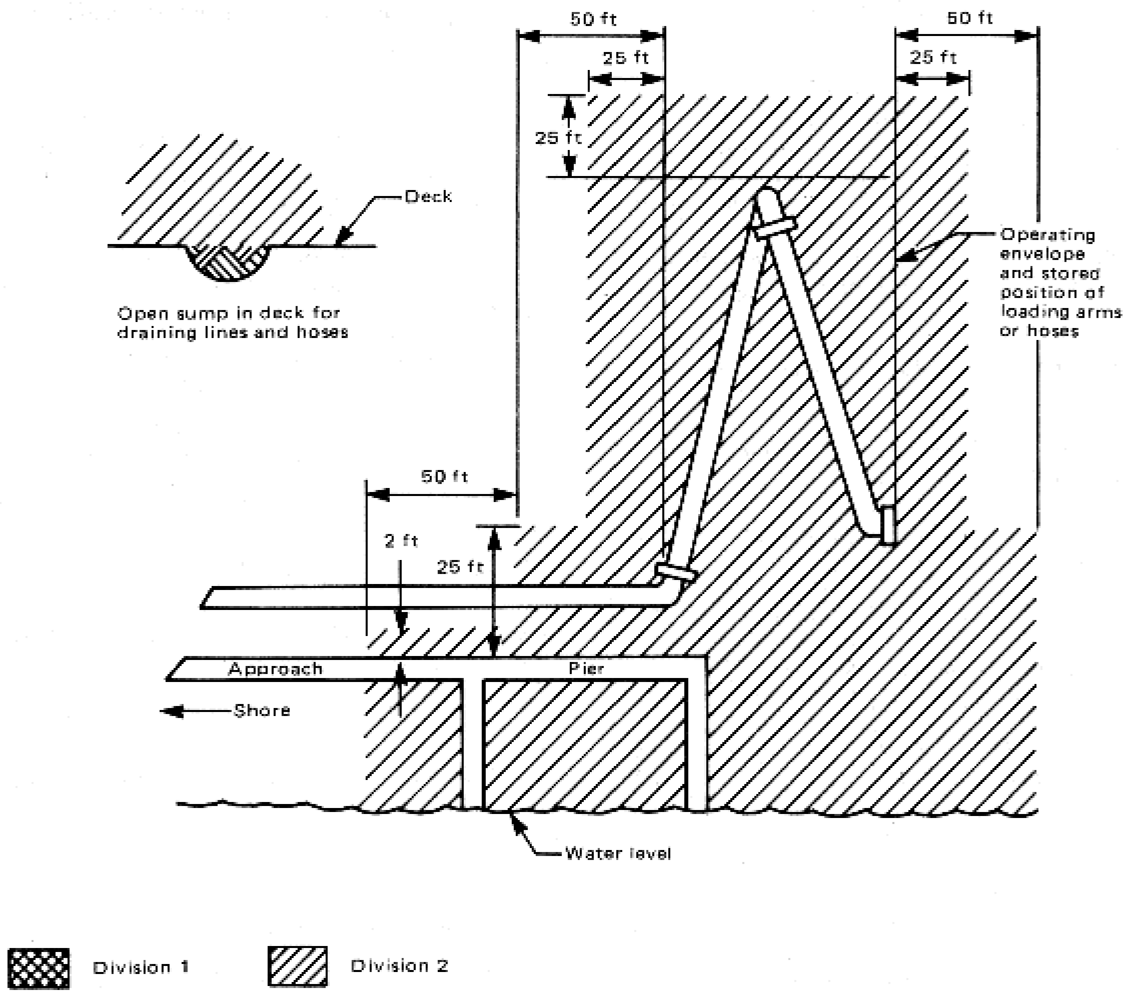


Figure 3-4.33 Leakage source from routinely operating bleeds, equipment handling liquefied natural gas in an adequately ventilated building.



NOTES:

1. The "source of vapor" shall be the operating envelope and stored position of the outboard flange connection of the loading arm (or hose).
2. The berth area adjacent to tanker and barge cargo tanks is to be Division 2 to the following extent:
   (a) 25 ft (7.6 m) horizontally in all directions on the pier side from that portion of the hull containing cargo tanks.
   (b) From the water level to 25 ft (7.6 m) above the cargo tanks at their highest position.
3. Additional locations may have to be classified as required by the presence of other sources of flammable liquids or by Coast Guard or other regulations.

MATERIAL: Flammable Liquids

Figure 3-4.34 Marine terminal handling flammable liquids.

Chapter 4 Referenced Publications

4-1

The following documents or portions thereof are referenced within this recommended practice and should be considered part of the recommendations of this document. The edition indicated for each reference is the current edition as of the date of the NFPA issuance of this document.

4-1.1 NFPA Publications.

National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.

NFPA 30, *Flammable and Combustible Liquids Code*, 1990 edition

NFPA 58, *Standard for the Storage and Handling of Liquefied Petroleum Gases*, 1992 edition

NFPA 59A, *Standard for the Production, Storage, and Handling of Liquefied Natural Gas (LNG)*, 1990 edition

NFPA 70, *National Electrical Code*, 1990 edition

4-1.2 API Publication.

American Petroleum Institute, 2101 L Street, NW, Washington, DC 20037.

API Recommended Practice 500A, *Classification of Locations for Electrical Installations in Petroleum Refineries*, Fourth Edition, 1982

Appendix A Referenced Publications

A-1

The following documents or portions thereof are referenced within this recommended practice for informational purposes only and thus should not be considered part of the recommendations of this document. The edition indicated for each reference is the current edition as of the date of the NFPA issuance of this document.

A-1.1 NFPA Publications.

National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.

NFPA 33, *Standard for Spray Application Using Flammable and Combustible Materials*, 1989 edition

NFPA 34, *Standard for Dipping and Coating Processes Using Flammable or Combustible Liquids*, 1989 edition

NFPA 35, *Standard for the Manufacture of Organic Coatings*, 1987 edition

NFPA 36, *Standard for Solvent Extraction Plants*, 1988 edition

NFPA 45, *Standard on Fire Protection for Laboratories Using Chemicals*, 1991 edition

NFPA 50A, *Standard for Gaseous Hydrogen Systems at Consumer Sites*, 1989 edition

NFPA 50B, *Standard for Liquefied Hydrogen Systems at Consumer Sites*, 1989 edition

1991 Edition

Recommended Practice for the Classification of Class II Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas

1991 Edition

This edition of NFPA 497B, *Recommended Practice for the Classification of Class II Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas*, was prepared by the Technical Committee on Electrical Equipment in Chemical Atmospheres and acted on by the National Fire Protection Association, Inc. at its Fall Meeting held November 12-14, 1990 in Miami, FL. It was issued by the Standards Council on January 11, 1991, with an effective date of February 8, 1991.

The 1991 edition of this document has been approved by the American National Standards Institute.

Origin and Development of NFPA 497B

The Committee on Electrical Equipment in Chemical Atmospheres began the development of this recommended practice in 1989. The Committee based the diagrams in this document on various codes and standards of the National Fire Protection Association and on the accepted practices of the chemical process industries. This is the first edition of this recommended practice, and it was adopted by the Association at the 1990 Fall Meeting.

Technical Committee on Electrical Equipment in Chemical Atmospheres

Richard Y. Le Vine, *Chairman*
Stamford, CT

Mark C. Ode, *Secretary*
National Fire Protection Association
(Nonvoting)

Alonza W. Ballard, Crouse-Hinds ECM
Rep. NEMA

Albert A. Bartkus, Underwriters Laboratories Inc.

Michael Kane Baucom, BEBCO Industries, Inc.

Carol M. Boring, U.S. Dept of Labor, MSHA

David H. Byford, Unocal Corp.
Rep. API

James C. Cawley, U.S. Bureau of Mines

David A. Heywood, U.S. Testing Co.

William G. Lawrence, Jr., Factory Mutual Research Corp.

Ernest C. Magison, Honeywell Inc.
Rep. ISA

Richard C. Masek, Bailey Controls

Robert E. McKenney, Dept. of Public Utilities

Charles R. Prasso, Industrial Risk Insurers

Milton H. Ramsey, Chevron USA Inc.
Rep. IEEE

John E. Rogerson, Cedar Lane Farm, OH

R. F. Schwab, Allied-Signal Inc.
Rep. Allied Corp.

George H. St. Onge, Bernardsville, NJ

David B. Wechsler, Union Carbide Corp.
Rep. CMA

Alternates

Edward M. Briesch, Underwriters Laboratories Inc.
(Alternate to A. A. Bartkus)

James A. Robertson, Dow Chemical Co. USA
(Alternate to M. H. Ramsey)

Daniel E. Vanover, U.S. Testing Co., Inc.
(Alternate to D. A. Heywood)

Mark C. Ode, NFPA Staff Liaison

This list represents the membership at the time the Committee was balloted on the text of this *edition. Since that time, changes in the membership may have occurred.*

NOTE: Membership on a Committee shall not in and of itself constitute an endorsement of the Association or any document developed by the Committee on which the member serves.

NFPA 497B
Recommended Practice for the
Classification of Class II Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas

1991 Edition

NOTICE: An asterisk (*) following the number or letter designating a paragraph indicates explanatory material on that paragraph in Appendix A.
Information on referenced publications can be found in Chapter 6 and Appendix B.

Chapter 1 General

1-1 Scope.

1-1.1

This recommended practice applies to those locations where combustible dusts are produced, processed, or handled and where dust released into the atmosphere or accumulated on surfaces may be ignited by electrical systems or equipment.

1-1.2

It also applies to chemical process areas. As used in this recommended practice, a chemical process area may be a chemical process plant, or it may be a part of such a plant. It may be a part of a manufacturing facility where combustible dusts are produced or used in chemical reactions or are handled or used in operations such as mixing, coating, extrusion, conveying, drying, grinding, etc.

1-1.3

This recommended practice does not apply to situations that may involve catastrophic failure of, or catastrophic discharge from, silos, process vessels, pipelines, tanks, hoppers, or conveying or elevating systems.

1-1.4

It does not apply to agricultural grain handling facilities except where powdered grain is used in a chemical reaction or mixture.

1-1.5

It does not apply to situations involving enriched oxygen atmospheres. It also does not apply to situations involving pyrophoric materials.

1-1.6

This recommended practice is not intended to supersede or conflict with applicable requirements of the following NFPA dust standards:

NFPA 36, *Solvent Extraction Plants*

NFPA 61A, *Manufacturing and Handling Starch*

NFPA 61B, *Grain Elevators and Facilities Handling Bulk Raw Agricultural Commodities*

NFPA 61C, *Feed Mills*

NFPA 61D, *Milling of Agricultural Commodities for Human Consumption*

NFPA 65, *Processing and Finishing of Aluminum*

NFPA 68, *Venting of Deflagrations*

NFPA 69, *Explosion Prevention Systems*

NFPA 85E, *Pulverized Coal-Fired Multiple Burner Boiler-Furnaces*

NFPA 85F, *Pulverized Fuel Systems*

NFPA 650, *Pneumatic Conveying Systems for Handling Combustible Materials*

NFPA 651, *Manufacture of Aluminum and Magnesium Powder*

NFPA 654, *Chemical, Dye, Pharmaceutical, and Plastics Industries*

NFPA 655, *Sulfur Fires and Explosions*

NFPA 664, *Wood Processing and Woodworking Facilities*

1-2 Purpose.

1-2.1

It is the intent of this recommended practice to provide the user with a basic understanding of the parameters that determine the degree and extent of the hazardous (classified) location. This document also provides the user with examples of the application of these parameters.

1-2.2

This recommended practice is intended as a guide and should be applied with sound engineering judgment. When all factors are properly evaluated, a consistent area classification scheme can be developed.

1-3 National Electrical Code® (NEC®).

1-3.1

This recommended practice is based on the criteria established by Articles 500 and 502 of NFPA 70, *National Electrical Code*. Once an area is properly classified, the *NEC* specifies the type of equipment and the wiring methods that may be used.

1-4 NFPA 497M.

1-4.1

NFPA 497M, *Classification of Gases, Vapors, and Dusts for Electrical Equipment in Hazardous (Classified) Locations*, provides information for determining if a dust is combustible based on the ignition sensitivity and explosion severity concepts specified in *Classification of Combustible Dust in Accordance with the National Electrical Code*, National Materials Advisory Board Publication 353-3.

Chapter 2 Basic Considerations

2-1 National Electrical Code Criteria.

2-1.1

Article 500 of NFPA 70, *National Electrical Code*, designates as hazardous (classified) any location in which a combustible material is or may be present in the atmosphere in sufficient concentration to produce an ignitible mixture. Article 500 defines three major categories of hazardous locations:

- Class I, in which the combustible material is a gas or vapor;
- Class II, in which the combustible material is dust;
- Class III, in which the combustible material is a fiber or flying.

This recommended practice is limited to Class II hazardous (classified) locations.

2-1.2

The intent of Article 500 is to prevent electrical equipment and systems in Class II hazardous (classified) locations from providing a means of ignition for an ignitible dust cloud or layer.

2-1.3

Within Class II hazardous (classified) locations, Article 500 recognizes two degrees of hazard: Division 1 and Division 2.

2-1.3.1 A Division 1 location is a location where (a) combustible dust is in the air under normal operating conditions in quantities sufficient to produce explosive or ignitible mixtures; or (b) mechanical failure or abnormal operation of machinery or equipment might cause such explosive or ignitible mixtures to be produced and might also provide a source of ignition through simultaneous failure of electrical equipment, operation of protection devices, or other causes; or (c) Group E dusts may be present in hazardous quantities.

2-1.3.2 A Division 2 location is a location where combustible dust is not normally in the air in quantities sufficient to produce explosive or ignitible mixtures, and dust accumulations are normally insufficient to interfere with the normal operation of electrical equipment or other apparatus. However, combustible dust may be in suspension in the air as a result of infrequent malfunctioning of handling or processing equipment and where combustible dust accumulations on, in, or in the vicinity of the electrical equipment may be sufficient to interfere with the safe dissipation of heat from electrical equipment or may be ignitible by abnormal operation or failure of electrical equipment.

NOTE: The quantity of combustible dust that may be present and the adequacy of dust removal systems are factors that merit consideration in determining the classification and may result in an unclassified area.

2-1.4

Electrical installations in Division 1 locations are designed and enclosed in a manner that will exclude ignitible amounts of dusts and will not permit arcs, sparks, or heat generated or liberated inside the enclosures to cause ignition of exterior dust accumulations on the enclosure or of atmospheric dust suspensions in the vicinity of the enclosure.

2-1.5

Electrical installations in Division 2 locations may be designed with dusttight enclosures or other equipment enclosures as specified in Article 502.

2-1.6

Electrical installations for classified locations may be designed in various manners. No single manner is best in all respects for all types of equipment used in a chemical plant. Dust-ignitionproof electrical equipment, pressurized electrical equipment, and intrinsically safe electrical equipment are applicable to both Division 1 and Division 2 locations. Other dusttight equipment enclosures as specified in Article 502 of NFPA 70, *National Electrical Code*, are permitted in Division 2 locations.

2-1.7

Equipment and wiring suitable for Class I, Division 1 locations are not required and may not be acceptable in Class II locations.

2-1.7.1 Where both combustible vapors and dusts are present, electrical equipment and wiring suitable for simultaneous exposure to both Class I and Class II conditions are required.

2-1.7.2 Where Group E dusts are present in hazardous quantities, there are only Division 1 locations. The *NEC* does not recognize any Division 2 areas for such dusts.

2-1.8

Factors such as corrosion, weather, maintenance, equipment standardization and interchangeability, and possible process changes or expansion frequently dictate the use of special enclosures or installations for electrical systems. However, such factors are outside the scope of this recommended practice, which is concerned entirely with the proper application of electrical equipment to avoid ignition of combustible dusts.

2-1.9

For the purpose of this recommended practice, locations that do not need to be classified as Division 1 or Division 2 are nonclassified locations.

2-2 Conditions Necessary for Ignition.

2-2.1*

In a Class II location, ignition may occur under three different sets of conditions.

2-2.1.1 In the first set of conditions,

(a) A combustible dust must be present.

(b) The dust must be suspended in the air in the proportions required to produce an ignitible mixture. Further, within the context of this recommended practice, a sufficient quantity of this suspension must be present in the vicinity of the electrical equipment.

(c) There must be a release of energy intense enough to cause ignition of the suspended mixture. Within the context of this recommended practice, the energy release is understood to originate within the electrical system.

2-2.1.2 In the second set of conditions,

(a) A combustible dust must be present.

(b) The dust must be layered on the electrical equipment sufficiently thick to interfere with the dissipation of heat and allow the layer to reach the ignition temperature of the dust.

(c) The external temperature of the electrical equipment must be high enough to cause the dust to reach its ignition temperature directly or to dry out the dust and cause it to self-heat.

2-2.1.3 In the third set of conditions,

(a) A Group E dust must be present.

(b) The dust must be layered or in suspension in hazardous quantities.

(c) Tracking must be sufficient to cause ignition. (*See 2-4.2.*)

2-2.2

Once ignition has occurred either in a cloud suspension or in a layer, an explosion is likely. Often the initial explosion is followed by another much more violent explosion fueled by the dust from dust accumulations on structural beams and equipment surfaces that are thrown into suspension by the initial blast. For this reason, good housekeeping in all areas handling dust is vitally important and is assumed throughout this recommended practice.

2-2.3

In classifying a particular location, the presence of a combustible dust is significant in determining the correct division. The classification depends both on the presence of dust clouds and on the presence of hazardous accumulations of dust in layer form. As defined in 2-1.3.1, the presence of a combustible dust cloud under normal conditions of operation, or due to frequent repair or maintenance, calls for a Division 1 classification. Abnormal operation of machinery and equipment, which may simultaneously produce a dust cloud or suspension and a source of ignition, also calls for a Division 1 classification. In other words, if a dust cloud is present at any time, it is assumed to be ignitible, and all that is necessary for electrical ignition is failure of the electrical system. If dust clouds or hazardous dust accumulations are present only as a result of infrequent malfunctioning of handling or processing equipment, and ignition can result only from abnormal operation or failure of electrical equipment, the location is designated as Division 2.

2-2.4

The presence of an ignitible dust cloud or an ignitible dust layer is important in determining the boundaries of the classified location. The quantity of dust, its physical and chemical properties, dust dispersion properties, and the location of walls and cutoffs must all be recognized.

2-3 Behavior of Dusts.

2-3.1 Dispersion and Explosion.

2-3.1.1 Dust discharged or leaking from equipment into the atmosphere is acted on by gravity and will settle relatively quickly depending on the size of particles, the internal pressure propelling the particles out of the equipment, and any air currents in the vicinity. The result is a layer of dust that settles on horizontal surfaces below the leak opening in a radial or elliptical manner, depending on the location of the opening on the equipment. The depth of the layer will be greatest under and close to the source and will taper off to the outside of the circle or ellipse. The greater the height of the dust source above the surface, the greater the area covered. The internal pressure in the equipment will likewise increase the area covered. The size of the leak opening and the elapsed time of emission also affect the quantity of dust on the surface. Some dusts have particles that are extremely fine and light (have a low specific particle density). Such particles may behave more like vapors than like dusts and may remain in suspension for long periods. These particles may travel far from the emitting source and collect on surfaces above the source. While horizontal surfaces accumulate the largest quantities of dust, vertical surfaces may in some instances also accumulate significant quantities.

2-3.1.2 While a dust cloud will ignite and explode readily in the presence of an open ignition source, dust layers, if undisturbed and not in direct contact with the ignition source, will not explode. However, if a small amount of dust is dispersed in the air at the ignition source, a small explosion will occur. The pressure wave from this explosion blows the dust layer into the air, and a larger explosion then takes place. It is often this secondary explosion that does the most damage.

2-3.2 Hybrid Dusts.

2-3.2.1 A hybrid dust is a mixture of a dust with one or more flammable gases or vapors. The presence of the flammable gas or vapor, even at concentrations less than their lower flammable limit (LFL), will not only add to the violence of the dust-air combustion but will drastically reduce the ignition energy. This situation is encountered in certain industrial operations, such as fluidized bed driers and pneumatic conveying systems for plastic dusts from polymerization processes where volatile solvents are used. In such cases, electrical equipment should be specified that is suitable for simultaneous exposure to both the Class I (flammable gas) and the Class II (combustible dust).

2-4 Classification of Dusts.

2-4.1

Class II combustible dusts are divided into three groups (Groups E, F, and G) based upon the nature of the dust.

The definitions of the three dust groups are as follows:

Group E: Atmospheres containing combustible metal dusts, including aluminum, magnesium, and their commercial alloys, or other combustible dusts whose particle size, abrasiveness, and conductivity present similar hazards in the use of electrical equipment.

Group F: Atmospheres containing combustible carbonaceous dusts, including carbon black, charcoal, coal, or coke dusts that have more than 8 percent total entrapped volatiles (*see ASTM D3175-82 for coal and coke dusts*) or that have been sensitized by other materials so that they present an explosion hazard.

Group G: Atmospheres containing other combustible dusts, including flour, grain, wood flour, plastic, and chemicals.

2-4.2

For purposes of classification, only Group E dusts shall be considered conductive. Group E dusts are sensitive to a phenomenon whereby an electric current finds the path of least resistance through a dust layer, heating up the dust particles in its path and thus providing a source of ignition. Thus, an electric arc may ignite a dust layer or a dust cloud. This phenomenon is commonly known as tracking.

Dusts containing magnesium or aluminum are particularly hazardous, and the use of extreme precaution will be necessary to avoid ignition and explosion.

Certain metal dusts may have characteristics that require safeguards beyond those required for atmospheres containing the dusts of aluminum, magnesium, and their commercial alloys. For example, zirconium, thorium, and uranium dusts have extremely low ignition temperatures [as low as 20°C (68°F)] and minimum ignition energies lower than any material classified in any of the Class I or Class II groups.

All areas where Group E dusts are present in hazardous quantities are classified as Division 1 locations. There are no Division 2 locations for Group E dusts.

2-4.3

A listing of selected combustible dusts appears in NFPA 497M, *Classification of Gases, Vapors, and Dusts for Electrical Equipment in Hazardous (Classified) Locations*, with their group classification and autoignition temperature of the cloud or layer, whichever is less.

2-5 Ignition of Dust Clouds.

2-5.1

The ignition energy required to ignite a dust cloud varies from dust to dust. However, the ignition energies are well below those that may be produced by most electrical sparks or an electrical fault; it is therefore not necessary to know the exact figure in order to classify areas for appropriate electrical equipment.

Exception: Intrinsically safe equipment energy levels are below the minimum ignition energies.

2-5.2

On the other hand, the cloud ignition temperature is important since the surface temperatures of both electrical and mechanical equipment in the area must be safely below this temperature.

2-5.3

Section 500-3(d) of the *NEC* specifies temperature limitations for Class II electrical equipment.

2-5.4

Some dusts that are not normally combustible may form explosive dust clouds when mixed with a flammable gas or vapor. (*See 2-3.2 Hybrid Dusts*.)

2-6 Ignition of Dust Layers.

2-6.1

The ignition temperature of a dust layer is a function of the type of dust and its physical and chemical properties. Where the dust covers electrical equipment that produces heat, such as lighting fixtures and motors, the dust acts as an insulator and leads to a heat buildup in the equipment and in the dust layer. As the thickness of the dust layer increases and the duration of exposure to the heat increases, the ignition temperature decreases and the dust ignites. Often the layer ignition temperature of the dust is less than the cloud ignition temperature of the dust.

2-6.2

The burning of the dust not only introduces an open flame ignition source that can ignite a dust cloud in the vicinity, but it also stirs up the dust layer, throwing dust into a cloud suspension.

2-6.3

Section 500-3(d) of the *NEC* specifies temperature limitations for Class II electrical equipment.

2-6.4

Some dusts in layers melt before they reach their layer ignition temperatures. In some cases, the melted material may then act more like a combustible liquid than a dust. Other materials, such as some polymers, degrade to a lower molecular weight material or to the monomer itself. This may introduce a flammable liquid problem into what was only a combustible dust problem. Materials such as unplasticized polyvinyl chloride, sulfur, and zinc stearate melt but cause only maintenance problems.

2-6.5

When subjected to heat, dusts of thermosetting plastics, such as phenol formaldehyde resins, tend to polymerize ("set up") and become hard. Continued heat buildup in the polymerized material ultimately leads to carbonization (degradation) of the material and a significantly lower ignition temperature. While this phenomenon is well known, there is no standardized test to define the precise parameters. Nonplastic materials such as sugar, cornstarch, and dextrine also carbonize and ignite at lower than expected temperatures.

Chapter 3 Degree of Hazard for Group F and G Dusts

3-1 Dust Layer Thickness.

3-1.1*

Generally speaking, the *NEC* indicates that (a) if there are explosive dust clouds under normal operating conditions, or (b) if such explosive dust clouds can be produced at the same time that a source of ignition is produced, then the area is a Division 1 location. The dust in (b) can be provided directly by some malfunction of machinery or equipment or can be provided by accumulations of dust on surfaces that are thrown into the air. Presumably, if all the dust on all surfaces in a room is sufficient to produce a dust concentration above the minimum explosive concentration, then that quantity of dust should define a Division 1 location.

From a practical point of view, a room with a concentration of dust that is above the minimum explosive concentration [criterion (a)] results in an atmosphere so dense that visibility beyond 3–5 ft (0.9 1.5 m) is impossible. Such a condition is unacceptable under today's standards for chemical plant work places. If such a situation were encountered, accumulations on horizontal surfaces would build up very rapidly.

On the other hand, working back from dust layers on horizontal surfaces in a room to a minimum explosive concentration in the room based on laboratory dust explosion tests shows a very thin layer of dust in the order of $^{1}/_{84}$ in. (0.3 mm) to be hazardous. This is an equally impractical answer since one of the most difficult experimental problems in dust explosion test work is to obtain a reasonably uniform cloud for ignition. As a result, the test apparatus is designed specifically to obtain uniform dust distribution. For dust lying on horizontal surfaces in a room or factory to attain such an efficient uniform distribution during an upset condition is obviously impossible.

3-2 Optimum Concentration Criteria.

3-2.1*

The optimum concentration is the concentration where the maximum rate of pressure rise is obtained under test conditions. Since the optimum concentration is far higher than the minimum explosive concentration, the layer thicknesses necessary to produce an optimum concentration are from 0.075 in. to 0.5 in. (1.9 mm   12.7 mm). There is then much more dust available to be thrown into uniform suspension without postulating a 100 percent efficiency of dispersal and distribution. In addition, there are a number of factors such as particle size and shape, moisture content, uniformity of distribution, etc., that negatively affect the susceptibility of a dust to ignition. Thus, dusts encountered in industrial plants tend to be less susceptible to ignition than those used in the laboratory to obtain explosion concentration data. The following classifications of areas are recommended, based on a buildup of the dust level in a 24-hr period on the major portions of the horizontal surfaces.

Thickness	Division
Greater than $^1/_8$ in. (3.18 mm)	1
$^1/_8$ in. (3.18 mm) and less but surface color not discernible	2
Surface color discernible under dust layer	Nonclassified

Based on these thicknesses of dust, good housekeeping can determine the difference between a classification of Division 1 and a classification of Division 2, and a classification of Division 2 and nonclassified. It should be emphasized, however, that housekeeping is a supplement to dust source elimination and mechanical ventilation. It is not a primary method of dust control.

3-3 Division 1 Classified Location.

3-3.1

The decision to classify a location as hazardous is based upon the possibility that an ignitible mixture of dust may be present. Having decided that a location should be classified, the next step is to determine the degree of hazard. Is the location Division 1 or Division 2?

3-3.2

As stated in 2-1.3.1 and 2-2.4, a condition for Division 1 is whether the location is likely to have an ignitible dust cloud or a thick layer of dust present under normal conditions. For example, the presence of ignitible dust suspensions and layers of dust in the vicinity of an open bagging operation is normal and requires a Division 1 classification.

3-3.3

Normal does not necessarily mean the situation that prevails when everything is working properly. For instance, there is a bucket elevator that requires frequent maintenance and repair. This is viewed as normal, and, if quantities of ignitible dust are released as a result of the maintenance, the location is Division 1. However, if that elevator is replaced and now repairs are not usually required between turnarounds, the need for repairs is considered abnormal. The classification of the location, therefore, is related to equipment maintenance, both procedures and frequencies. Similarly, if the problem is the buildup of dust layers without the presence of visible dust suspensions, good frequent cleaning procedures or the lack thereof will influence the classification of the area.

3-4 Division 2 Classified Location.

3-4.1

The criterion for a Division 2 location is whether the location is likely to have ignitible dust suspensions or hazardous dust accumulations only under abnormal conditions. The term "abnormal" is used here in a limited sense and does not include a major catastrophe.

3-4.2

As an example, consider the new bucket elevator of 3-3.3, which releases ignitible dust only under abnormal conditions. In this case there is no Division 1 location because the elevator is normally tight. To release dust, the elevator would have to leak, and that would not be normal. Thus, the elevator is surrounded by a Division 2 location.

3-4.3

Chemical process equipment does not fail often. Furthermore, the electrical installation requirement of NFPA 70 for Division 2 locations is such that an ignition-capable spark or hot surface will occur only in the event of abnormal operation or failure of electrical equipment. Otherwise, sparks and hot surfaces are not present or are contained in enclosures. On a realistic basis, the possibility of process equipment and electrical equipment failing simultaneously is remote; this justifies the recognition and acceptance of the Division 2 concept.

3-4.4

The Division 2 classification is applicable to conditions not involving equipment failure. For example, consider a location classified as Division 1 because of normal presence of ignitible dust suspension. Obviously, one side of the Division 1 boundary cannot be normally hazardous and the opposite side never hazardous. Similarly, consider a location classified as Division 1 because of the normal presence of hazardous dust accumulations. One side of the division boundary cannot be normally hazardous with thick layers of dust and the other side nonhazardous with no dust unless there is an intervening wall. When there is no wall, a surrounding transition Division 2 location separates a Division 1 location from a nonclassified location.

3-4.5

Walls are much more important in separating Division 1 locations from Division 2 and nonclassified locations in Class II areas than in Class I areas. Only unpierced solid walls make satisfactory barriers in Class I areas, while walls with closed doors, lightweight partitions, even partial partitions, make satisfactory barriers between Class II, Division 1 locations and nonhazardous locations. Area classification does not extend beyond the barrier, provided any openings can be closed or are effective in preventing the passage of dust in suspension or layer form.

3-5 Nonclassified Locations.

3-5.1

Experience has shown that the release of ignitible dust suspensions from some operations and apparatus is so infrequent that area classification is not necessary. For example, it is usually not necessary to classify the following locations where combustible ground up solids are processed, stored, or handled:

- Locations where materials are stored in sealed containers — bags, drums, fiber packs — palletized or racked.

- Locations where materials are transported in well-maintained closed piping systems.

- Locations where palletized materials with minimal dust are handled or used.

- Locations where closed tanks are used for storage and handling.

- Locations where mechanical dust collection systems on equipment prevent (a) visual dust clouds or (b) layer accumulations that make surface colors indiscernible. (*See 3-2.1*.)

- Locations where excellent housekeeping is maintained and there are (a) no visual dust suspensions or (b) layer accumulations that make surface colors indiscernible. (*See 3-2.1*.)

3-5.2

Mechanical dust collection systems that are provided on equipment to allow a nonclassified location must have adequate safeguards and warnings against failure.

3-5.3

Open flames and hot surfaces associated with the operation of certain equipment, such as boilers and fired heaters, provide inherent thermal ignition sources. Electrical classification is not appropriate in the immediate vicinity of these facilities. Dust containing operations should be cut off by blank walls or located away from such facilities. Where pulverized coal or ground up solid waste is used to fire a boiler or incinerator, consideration should be given to potential leak sources in fuel feed lines to the burners to avoid installing electrical devices that could in themselves become primary ignition sources for such leaks.

Chapter 4 Extent of Classified Locations

4-1 Extent of Classified Locations.

4-1.1

This chapter deals with the extent of Division 1 or Division 2 locations. References to Division 2 locations apply only to Group F or G dusts. Careful consideration of the following factors is necessary in determining the extent of the locations:

- the combustible material involved

- the bulk density of the material

- the particle sizes of the material

- the density of the particles

- the process or storage pressure

- the size of the leak opening

- the quantity of the release

- the dust collection system
- the housekeeping
- the presence of any flammable or combustible gas.

4-1.2

The dispersal of dusts and the influence of the above factors on this dispersal were discussed generally in Sections 2-3, 2-4, 2-5, and 2-6. The influence of dust collection and housekeeping were discussed generally in other paragraphs of this chapter.

4-1.3

In addition, walls, partitions, enclosures, or other barriers and strong air currents will also affect the distance that dust particles will travel and the extent of the Division 1 and Division 2 locations.

4-1.4

Where there are walls that limit the travel of the dust particles, area classifications do not extend beyond the walls. Enclosing rooms, walls, and partitions are a primary means of limiting the extent of hazardous locations.

4-1.5

Where there are no effective walls involved, the extent of the Division 1 and Division 2 locations can be estimated as follows:

- By visual observation of the existing area using the guidelines of 3-2.1.
- By experience with similar dusts and similar operations and taking into consideration any new equipment, any new enclosures, any new mechanical dust collection, and any changes in housekeeping rules and methods.
- By calculation.

4-1.6

Tight equipment, mechanically ventilated hoods and pickup points, adequate maintenance, and housekeeping should limit Division 1 locations to the inside of process enclosures and equipment and close to openings necessary for transfer of material such as from conveyors to grinders to storage bins to bags. Similarly, such good engineering will also limit the Division 2 location surrounding the Division 1 location.

4-1.7

The size of a building and its walls will influence the classification of the enclosed volume. In the case of a small room, it may be appropriate to classify the entire volume as Division 1 or Division 2.

4-1.8

When classifying large buildings, careful evaluation of prior experience with the same or similar installations should be made. Where experience indicates that a particular design concept is sound, a more hazardous classification for similar installations may not be justified. On the other hand, where experience indicates a particular design concept results in an unsatisfactory dust condition, sound engineering judgment is essential in reducing the extent of the hazardous locations based on engineering changes.

4-1.8.1 Wherever possible with large buildings, walls should be used to cut off dusty operations to avoid extensive use of special electrical equipment. Where walls are not possible, the concentric volume approach of a Division 1 location surrounded by a larger Division 2 location may be satisfactory.

4-1.8.2 Where a number of dusty operations are located in a building, it may be satisfactory to have a multiplicity of Division 1 locations with the intervening Division 2 and nonclassified locations.

4-1.9

The quantity of dust released and its distance of travel is of extreme importance in determining the extent of a hazardous location, and it is this consideration that necessitates the greatest application of sound engineering judgment. However, one cannot lose sight of the purpose of this judgment; the location is classified solely for the installation of electrical equipment.

Chapter 5 Determining the Degree and Extent of Hazardous (Classified) Locations

5-1 Diagrams and Recommendations.

5-1.1

This chapter contains a series of diagrams that illustrate how typical dusty sites should be classified and the recommended extent of the various classifications.

5-1.2

The intended use of the diagrams is to aid in developing electrical classification maps of operating units, storage areas, and process buildings. Most of the diagrams are plan views. Elevations may be necessary to provide the three-dimensional picture of an actual operation.

5-1.3

These diagrams apply to operating equipment processing dusts when the specific particle density is greater than 40 lb/cu ft (640.72 kg/m^3). When dusts with a specific particle density less than 40 lb/cu ft (640.72 kg/m^3) are being handled there is a pronounced tendency for the fine dust to drift on air currents normally present in industrial plants for distances considerably farther than those shown on these diagrams. In those cases it will be necessary to extend the classified area. It is difficult to recommend precise classified areas in these circumstances.

5-1.4

Good engineering practices, good housekeeping practices, and dust control systems are necessary to limit the extent of the classified locations and to minimize the chances of primary and the often more violent secondary explosions.

5-1.5

An operating unit may have many interconnected sources of pulverized combustible materials such as storage tanks, bins and silos, piping and ductwork, hammer mills, ball mills, grinders, pulverizers, milling machines, conveyors, bucket elevators, and bagging or other packaging machines. These in turn present sources of leaks such as flanged and screwed connections, fittings, openings, valves, and metering and weighing devices. Thus, actual diagrams of the equipment may be required so that the necessary engineering judgment to establish the boundaries of Division 1 and Division 2 locations may be applied properly.

5-2 Procedure for Classifying Locations.

The following procedure should be used for each room, section, or area being classified.

5-2.1 Step One — Need for Classification:

The area should be classified if the answer to the following question is "Yes."

(a) Are combustible dusts likely to be present?

5-2.2 Step Two — Assignment of Division Classification:

Assuming an affirmative answer to Step One, the following questions should be answered to determine the correct division classification.

5-2.2.1 Division 1 locations are distinguished by a "Yes" answer to any one of the following questions:

(a) Is a Group E dust present in hazardous quantities?

(b) Is a dust likely to be in suspension in air continuously, periodically, or intermittently under normal conditions in quantities sufficient to produce explosive or ignitible mixtures?

(c) Will mechanical failure or abnormal operation of machinery or equipment cause such explosive or ignitible mixtures to be produced, and might it also provide a source of ignition through simultaneous failure of electrical equipment operation of protective devices or from other causes?

(d) Are there dust layers or accumulations on surfaces deeper than $^1/_8$ in. (3.18 mm)?

5-2.2.2 Division 2 locations for Group F or G dusts are distinguished by a "Yes" answer to any of the following questions:

(a) Is the dust not normally in suspension in the air in quantities sufficient to produce explosive or ignitible mixtures, but could it be thrown into suspension by infrequent malfunctioning of handling or processing equipment?

(b) Are the dust accumulations insufficient to interfere with the normal operation of electrical equipment, but could the accumulations be ignited by the abnormal operation or failure of electrical equipment?

(c) Is there a dust layer that makes the colors of the surfaces indiscernible?

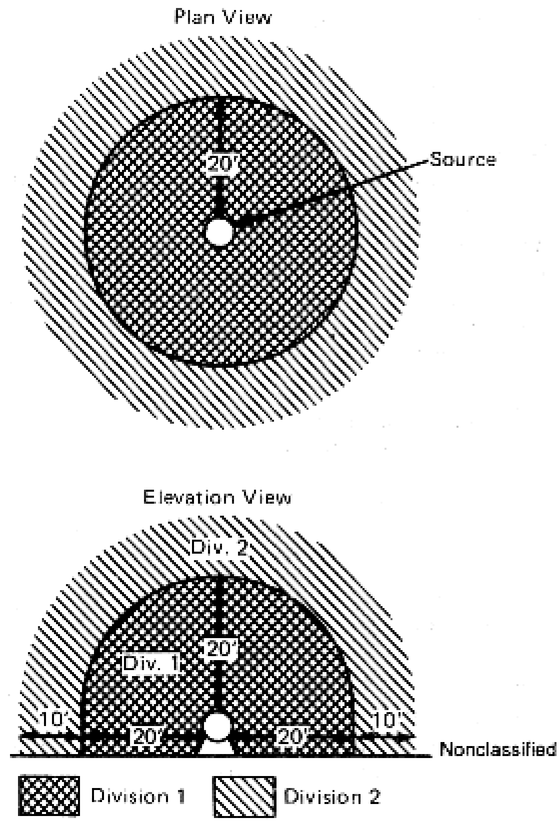
(d) Would the failure of mechanical dust collection allow an ignitible suspension of dust or a layer deeper than $^1/_8$ in. (3.18 mm) to build up?

5-2.3 Step Three — Extent of Classified Location:

The extent of the classified location may be determined by applying, with sound engineering judgment, the methods discussed in 4-1.5 and the diagrams contained in this chapter.

5-3 Index of Classification Diagrams.

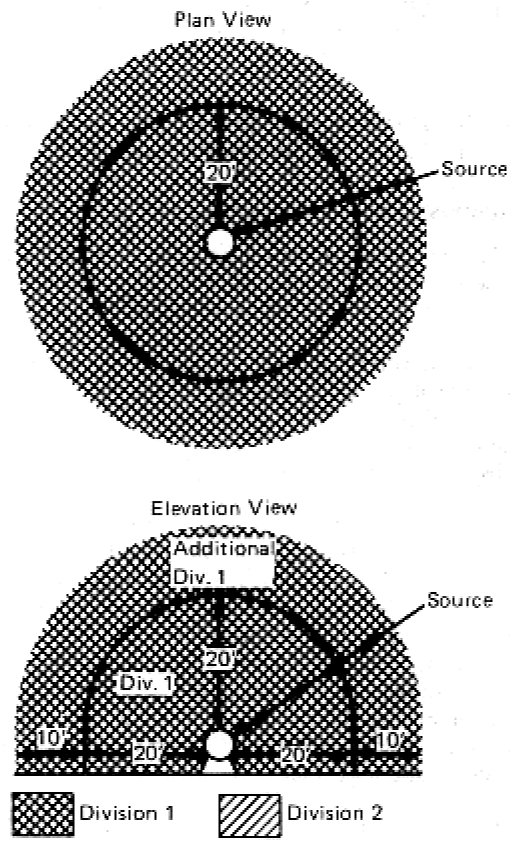
This section contains descriptions of the classification diagrams that follow.



Description of Dust Condition

DIVISION 1	DIVISION 2
Moderate or dense dust cloud. Dust layer greater than 1/8 in. (3.18 mm).	No visible dust cloud. Dust layer less than 1/8 in. (3.18 mm) and surface color not discernible.

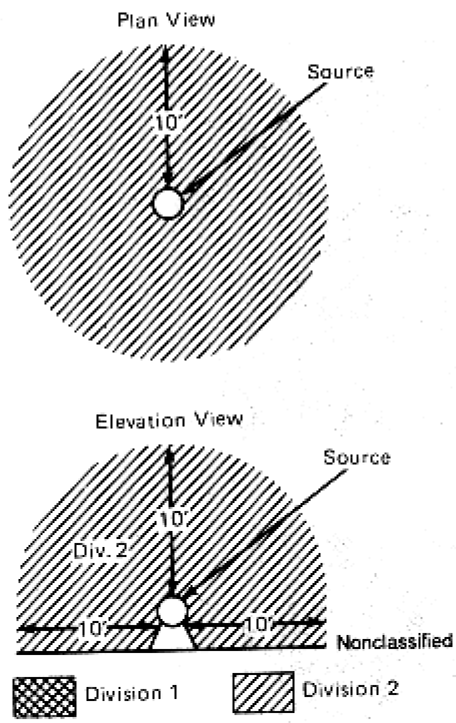
Figure 5-3.1 Group F or Group G dust—indoor unrestricted area, open or semienclosed equipment.



Description of Dust Condition

DIVISION 1	ADDITIONAL DIVISION 1
Moderate or dense dust cloud or dust layer greater than 1/8 in. (3.18 mm).	Dust layer less than 1/8 in. (3.18 mm) and surface color not discernible.

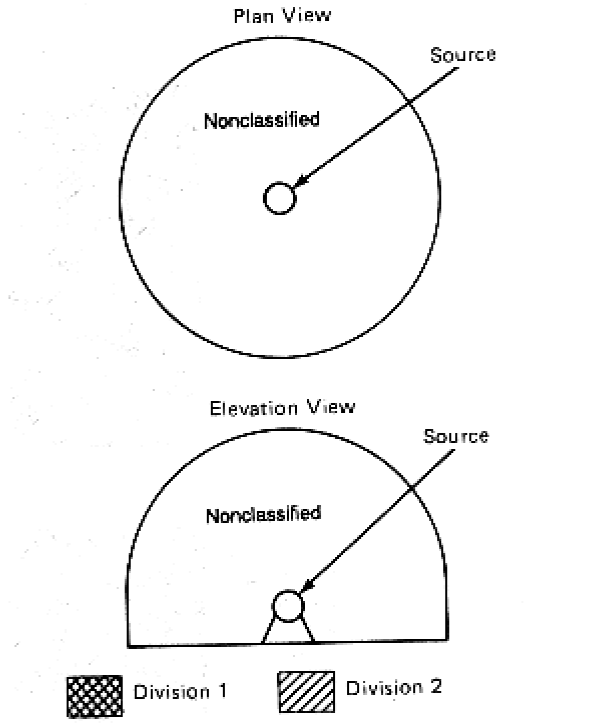
Figure 5-3.2 Group E dust—indoor unrestricted area, open or semienclosed operating equipment.



Description of Dust Condition

DIVISION 1	DIVISION 2
None	No visible dust cloud. Dust layer less than 1/8 in. (3.18 mm) and surface color notdiscernible.

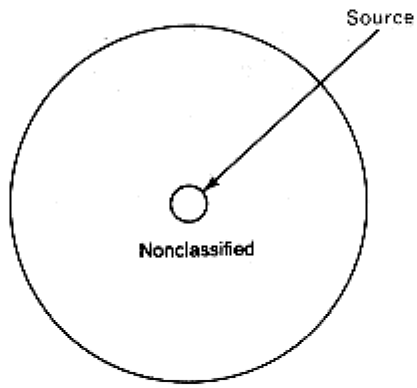
Figure 5-3.3 Group F or Group G dust—indoor unrestricted area, operating equipment enclosed.



Description of Dust Condition

DIVISION 1	DIVISION 2	NONCLASSIFIED
None	None	Surface color discernible.

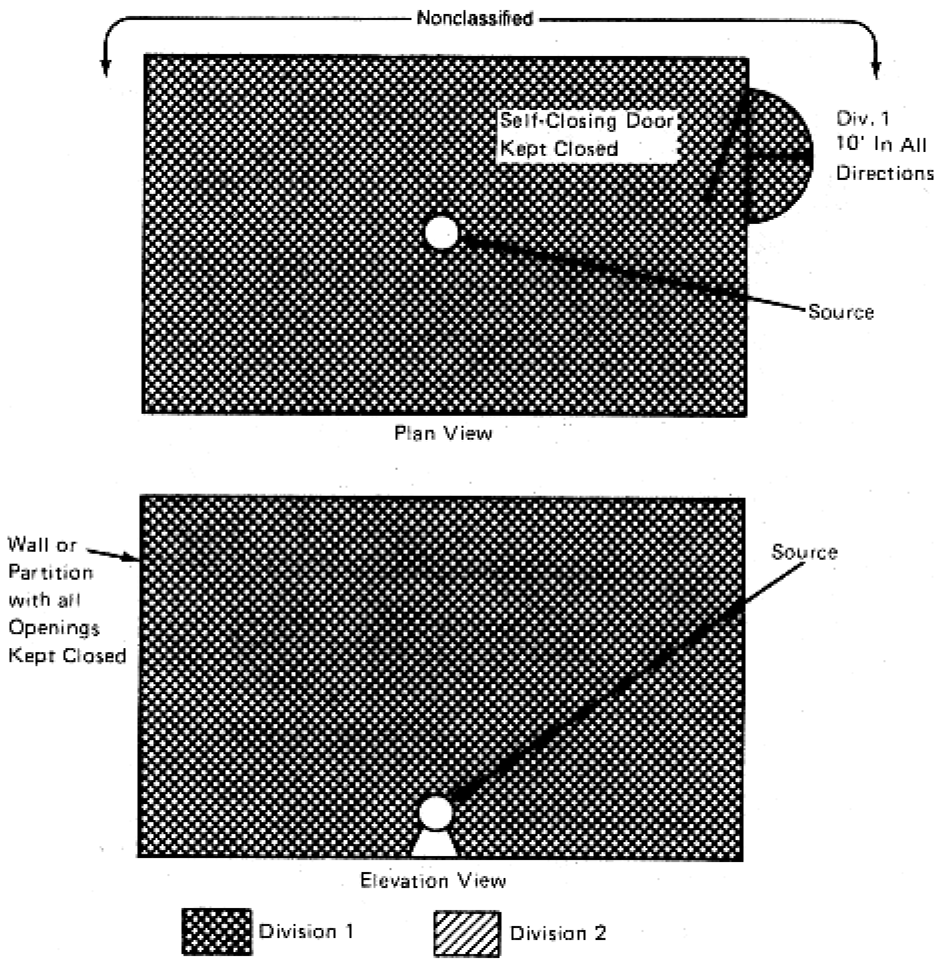
Figure 5-3.4 Group F or Group G dust—indoor unrestricted area, operating equipment enclosed.



Description of Dust Condition

DIVISION 1	DIVISION 2	NONCLASSIFIED
None	None	Dust layer not apparent. Surface color discernible.

Figure 5-3.5 Groups E, F, or G dusts—storage area bags, drums, or closed hoppers.



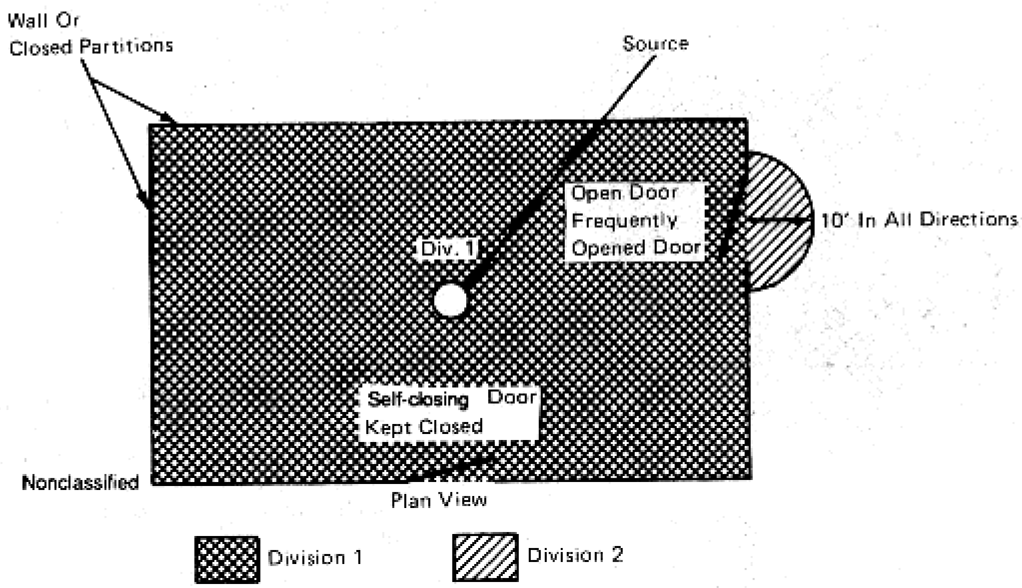
Description of Dust Condition

Minimize Division 1 Cutoff Volume and Area

Description of Equipment/Area Control

Maximize Confinement
Maximize Dust Control
Maximize Housekeeping
See 5-1.4

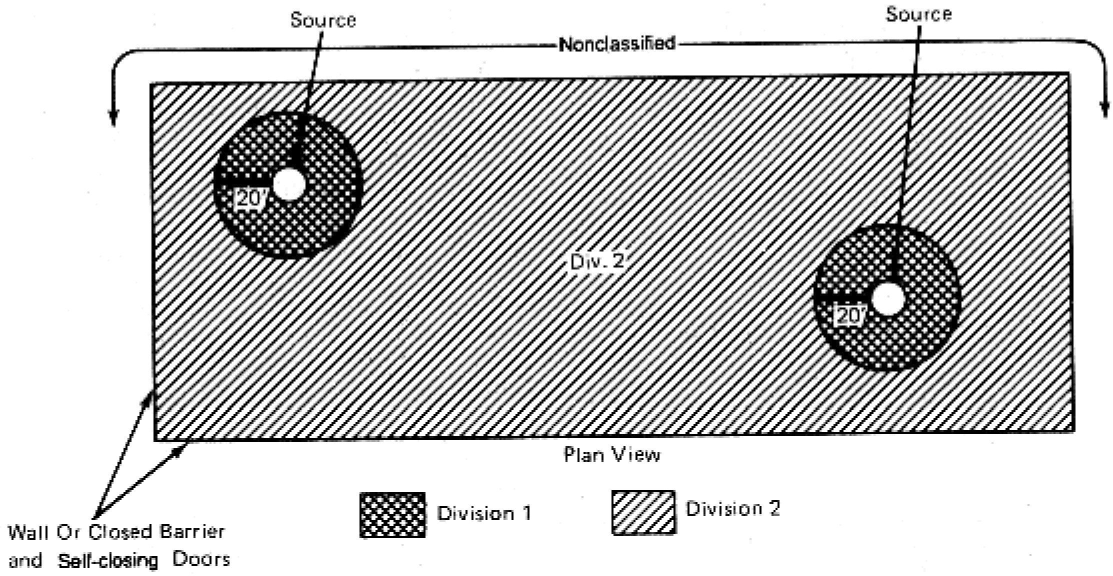
Figure 5-3.6 Group E dust—inside walled off area; operating equipment enclosed.



Description of Dust Condition

DIVISION 1	DIVISION 2
Moderate to dense dust cloud or dust layer greater than 1/8 in. (3.18 mm).	No visible dust cloud. Dust layer less than 1/8 in. (3.18 mm) but surface color not discernible.

Figure 5-3.7 Group F or G indoor walled off area; operating equipment open or semienclosed.



Description of Dust Condition

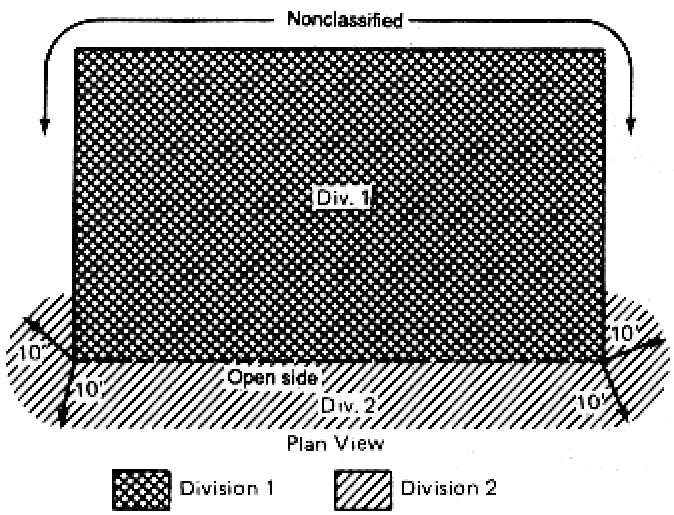
DIVISION 1

Moderate to dense dust cloud. Dust layer greater than ⅛ in. (3.18 mm).

DIVISION 2

No visible dust cloud. Dust layer less than ⅛ in. (3.18 mm) and surface color not discernible.

Figure 5-3.8 Group F or Group G indoor walled off area; multiple operating equipment.



Description of Dust Condition

DIVISION 1	DIVISION 2
Moderate to dense dust cloud or dust layer greater than $\frac{1}{8}$ in. (3.18 mm).	No visible dust cloud. Dust layer less than $\frac{1}{8}$ in. (3.18 mm) and surface color not discernible.

Figure 5-3.9 Group F or Group G indoor unrestricted area ventilated bagging head.

Chapter 6 Referenced Publications

6-1

The following documents or portions thereof are referenced within this recommended practice and should be considered part of the recommendations of this document. The edition indicated for each reference is the current edition as of the date of the NFPA issuance of this document.

6-1.1 NFPA Publications.

National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.

NFPA 70, *National Electrical Code*, 1990 edition

NFPA 497M, *Manual for Classification of Gases, Vapors, and Dusts for Electrical Equipment in Hazardous (Classified) Locations*, 1991 edition

6-1.2 ASTM Publication.

American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103.

ASTM D3175-82, *Standard Test Method for Volatile Matter in the Analysis Sample of Coal and Coke*

Appendix A

This Appendix is not a part of the recommendations of this NFPA document, but is included for information purposes only.

A-2-2.1

Open flames and welding and cutting operations have far more energy and heat than most electrical fault sparks and arcs and are quite capable of igniting dusts. Hot surfaces such as those in some heaters, or caused by continuous friction, may also have sufficient heat to ignite dusts. Such sources of ignition must therefore be carefully controlled.

A-3-1.1

A typical calculation considers cornstarch with a powder bulk density of approximately 25 lb/ft^3. The minimum explosive concentration is 0.04 oz/ft^3. In a room 10 ft high by 10 ft wide by 10 ft long, calculate the depth of dust that would accumulate on the floor if the room were completely filled with a cornstarch cloud at the minimum concentration.

$$\frac{0.04\ \text{oz}}{\text{ft}^3} \times 1000\ \text{ft}^3 \times \frac{1\ \text{lb}}{16\ \text{oz}} \times \frac{1\ \text{ft}^3}{25\ \text{lb}} = 0.1\ \text{ft}^3 \text{ of dust on the floor}$$

Evenly distributed over 100 sq ft, the depth of dust would be:

$$\frac{0.1\ \text{ft}^3}{100\ \text{ft}^2} = 0.001\ \text{ft} = 0.012\ \text{in. } (^1/_{84}\ \text{in. thick})$$

Theoretically, throwing this amount of dust back from the floor and ledges into the room volume would create a hazardous condition. Accomplishing such a feat, even experimentally, would be virtually impossible.

A-3-2.1

The following table shows the theoretical thickness of dust on the floor of a 10 ft × 10 ft × 10 ft room necessary to satisfy the concentration requirements for a uniform dust cloud of minimum explosive concentration and for a uniform dust cloud of optimum concentration for four dusts.

Table A-3-2.1

	Min. Conc.	Depth of Dust	Opt. Conc.	Depth of Dust	Bulk Density
	oz/ft^3	In.	oz/ft^3	In.	lb/ft^3
Cornstarch	0.04	0.012	0.5	0.15	25-50
Cork	0.035	0.022	0.2	0.125	12-15

Sugar	0.045	0.0068	0.5	0.075	50-55
Wood Flour	0.035	0.016	1.0	0.47	16-36
Polyethylene	0.020	0.0072	0.5	0.180	21-35
(Low Density)					

Appendix B Referenced Publications

B-1

The following documents or portions thereof are referenced within this recommended practice for informational purposes only and thus are not considered part of the recommendations of this document. The edition indicated for each reference is the current edition as of the date of the NFPA issuance of this document.

B-1.1 NFPA Publications.

National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.

NFPA 36, *Standard for Solvent Extraction Plants*, 1988 edition

NFPA 61A, *Standard for Prevention of Fire and Dust Explosions in Facilities Manufacturing and Handling Starch*, 1989 edition

NFPA 61B, *Standard for the Prevention of Fires and Explosions in Grain Elevators and Facilities Handling Bulk Raw Agricultural Commodities*, 1989 edition

NFPA 61C, *Standard for the Prevention of Fire and Dust Explosions in Feed Mills*, 1989 edition

NFPA 61D, *Standard for the Prevention of Fire and Dust Explosions in the Milling of Agricultural Commodities for Human Consumption*, 1989 edition

NFPA 65, *Standard for the Processing and Finishing of Aluminum*, 1987 edition

NFPA 68, *Guide for Venting of Deflagrations*, 1988 edition

NFPA 69, *Standard on Explosion Prevention Systems*, 1986 edition

NFPA 85E, *Standard for Prevention of Furnace Explosions in Pulverized Coal-Fired Multiple Burner Boiler-Furnaces*, 1985 edition

NFPA 85F, *Standard for the Installation and Operation of Pulverized Fuel Systems*, 1988 edition

NFPA 650, *Standard for Pneumatic Conveying Systems for Handling Combustible Materials*, 1990 edition

NFPA 651, *Standard for the Manufacture of Aluminum and Magnesium Powder*, 1987 edition

NFPA 654, *Standard for the Prevention of Fire and Dust Explosions in the Chemical, Dye, Pharmaceutical, and Plastics Industries*, 1988 edition

NFPA 655, *Standard for the Prevention of Sulfur Fires and Explosions*, 1988 edition

NFPA 664, *Standard for the Prevention of Fires and Explosions in Wood Processing and Woodworking Facilities*, 1987 edition

B-1.2 National Academy of Sciences Publication.

National Materials Advisory Board of the National Academy of Sciences, 2101 Constitution Avenue, NW, Washington, DC 20418.

NMAB 353-3, *Classification of Combustible Dusts in Accordance with the National Electrical Code*

NFPA 497M

1991 Edition

Manual for Classification of Gases, Vapors, and Dusts for

Electrical Equipment in Hazardous (Classified) Locations

1991 Edition

This edition of NFPA 497M, *Manual for Classification of Gases, Vapors, and Dusts for Electrical Equipment in Hazardous (Classified) Locations*, was prepared by the Technical Committee on Electrical Equipment in Chemical Atmospheres and acted on by the National Fire Protection Association, Inc. at its Fall Meeting held November 12–14, 1990 in Miami, FL. It was issued by the Standards Council on January 11, 1991, with an effective date of February 8, 1991, and supersedes all previous editions.

The 1991 edition of this document has been approved by the American National Standards Institute.

Changes other than editorial are indicated by a vertical rule in the margin of the pages on which they appear. These lines are included as an aid to the user in identifying changes from the previous edition.

Origin and Development of NFPA 497M

In May, 1980, the 1981 edition of NFPA 70, *National Electrical Code*,® was proposed for adoption. Article 500 of this edition of the NEC® contained extensive lists of gases, vapors, and dusts, and their group classifications, as recommended by the National Materials Advisory Board of the National Academy of Sciences. Upon recommendation of the NFPA Technical Committee on Electrical Equipment in Chemical Atmospheres, these lists were removed from the 1981 NEC. The Technical Committee justified this action by claiming that the entries in the lists did not receive adequate review, were, in some cases, incorrect, and, in other cases, greatly overstated the hazard. Code-Making Panel 14 of the National Electrical Code Committee, the body responsible for Article 500, gave the Technical Committee the task of reviewing and amending the lists and requested that a classification manual be developed in time to be adopted by the Association prior to the next edition of the NEC.

The Technical Committee on Electrical Equipment in Chemical Atmospheres immediately developed criteria for gases, vapors, and dusts for the classification lists. Using these criteria, the Committee reviewed the NMAB lists and removed some materials that the Committee felt did not warrant classification. As a result of the public review and comment period, the Committee revised its criteria and expanded the lists significantly.

The information in this manual is intended to aid the engineer in specifying electrical equipment for hazardous (classified) locations in compliance with the *National Electrical Code*.

This manual was first adopted by the Association at its 1982 Fall Meeting. Amendments were adopted at the 1985 Fall Meeting and the 1990 Fall Meeting.

Rep. ISA

Richard C. Masek, Bailey Controls

Robert E. McKenney, Dept. of Public Utilities

Charles R. Prasso, Industrial Risk Insurers

Milton H. Ramsey, Chevron USA Inc.
Rep. IEEE

John E. Rogerson, Cedar Lane Farm, OH

R. F. Schwab, Allied-Signal Inc.
Rep. Allied Corp.

George H. St. Onge, Bernardsville, NJ

David B. Wechsler, Union Carbide Corp.
Rep. CMA

Alternates

Edward M. Briesch, Underwriters Laboratories Inc.
(Alternate to A. A. Bartkus)

James A. Robertson, Dow Chemical Co. USA
(Alternate to M. H. Ramsey)

Daniel E. Vanover, U.S. Testing Co., Inc.
(Alternate to D. A. Heywood)

Mark C. Ode, NFPA Staff Liaison

This list represents the membership at the time the Committee was balloted on the text of this edition. Since that time, changes in the membership may have occurred.

NOTE: Membership on a Committee shall not in and of itself constitute an endorsement of the Association or any document developed by the Committee on which the member serves.

Manual for Classification of Gases,Vapors, and Dusts for Electrical Equipment in Hazardous(Classified) Locations

1991 Edition

NOTICE: An asterisk (*) following the number or letter designating a paragraph indicates explanatory material on that paragraph in Appendix A.

Information on referenced publications can be found in Chapter 4 and Appendix C.

Chapter 1 General

1-1 Scope.

This manual provides information on specific flammable gases, flammable and combustible liquids, and combustible dusts whose relevant combustion properties have been identified sufficiently to allow their classification into the groups established by the *National Electrical Code* for proper selection of electrical equipment in hazardous (classified) locations. The tables in this manual are not intended to be all inclusive.

1-2 Purpose.

The purpose of this manual is to assist in the selection of special electrical equipment for hazardous (classified) areas where such electrical equipment is required. *(See Article 500 of NFPA 70, National Electrical Code*.)

1-3 Definitions.

For the purpose of this manual, the following terms shall have the meanings given below:

Approved. Acceptable to the "authority having jurisdiction."

NOTE: The National Fire Protection Association does not approve, inspect or certify any installations, procedures, equipment, or materials nor does it approve or evaluate testing laboratories. In determining the acceptability of installations or procedures, equipment or materials, the authority having jurisdiction may base acceptance on compliance with NFPA or other appropriate standards. In the absence of such standards, said authority may require evidence of proper installation, procedure or use. The authority having jurisdiction may also refer to the listings or labeling practices of an organization concerned with product evaluations which is in a position to determine compliance with appropriate standards for the current production of listed items.

Authority Having Jurisdiction. The "authority having jurisdiction" is the organization, office or individual responsible for "approving" equipment, an installation or a procedure.

NOTE: The phrase "authority having jurisdiction" is used in NFPA documents in a broad manner since jurisdictions and "approval" agencies vary as do their responsibilities. Where public safety is primary, the "authority having jurisdiction" may be a federal, state, local or other regional department or individual such as a fire chief, fire marshal, chief of a fire prevention bureau, labor department, health department, building official, electrical inspector, or others having statutory authority. For insurance purposes, an insurance inspection department, rating bureau, or other insurance company representative may be the "authority having jurisdiction." In many circumstances the property owner or his designated agent assumes the role of the "authority having jurisdiction"; at government installations, the commanding officer or departmental official may be the "authority having jurisdiction."

Autoignition Temperature. The minimum temperature required to initiate or cause self-sustained combustion of a solid, liquid, or gas independently of the heating or heated element. *(See NFPA 325M, Fire Hazard Properties of Flammable Liquids, Gases, and Volatile Solids*.)

Class I, Division 1. A location (1) in which ignitible concentrations of flammable gases or vapors exist under normal operating conditions; or (2) in which ignitible concentrations of such gases or vapors may exist frequently because of repair or maintenance operations or because of leakage; or (3) in which breakdown or faulty operation of equipment or processes might release ignitible concentrations of flammable gases or vapors and might also cause simultaneous failure of electrical equipment. [*See Section 500-5(a) of NFPA 70, National Electrical Code*.]

Class I, Division 2. A location (1) in which volatile flammable liquids or flammable gases are handled, processed, or used, but in which the liquids, vapors, or gases will normally be confined within closed containers or closed systems from which they can escape only in case of accidental rupture or breakdown of such containers or systems, or in case of abnormal operation of equipment; or (2) in which ignitible concentrations of gases or vapors are normally prevented by positive mechanical ventilation, and which might become hazardous through failure or abnormal operation of the ventilating equipment; or (3) that is adjacent to a Class I, Division 1 location, and to which ignitible concentrations of gases or vapors might occasionally be communicated unless such communication is prevented by adequate positive-pressure ventilation from a source of clean air and effective safeguards against ventilation failure are provided. [*See Section 500-5(b) of NFPA 70, National Electrical Code*.]

Class II, Division 1. A location (1) in which combustible dust is in the air under normal operating conditions in quantities sufficient to produce explosive or ignitible mixtures; or (2) where mechanical failure or abnormal operation of machinery or equipment might cause such explosive or ignitible mixtures to be produced and might also provide a source of ignition through simultaneous failure of electrical equipment, operation of protection devices, or from other causes; or (3) in which combustible dusts of an electrically conductive nature may be present in hazardous quantities. [*See Section 500-6(a) of NFPA 70, National Electrical Code*.]

Class II, Division 2. A location where combustible dust is not normally in the air in quantities sufficient to produce explosive or ignitible mixtures, and dust accumulations are normally insufficient to interfere with the normal operation of electrical equipment or other apparatus, but combustible dust may be in suspension in the air as a result of infrequent malfunctioning of handling or processing equipment and where combustible dust accumulations on, in, or in the vicinity of, the electrical equipment may be sufficient to interfere with the safe dissipation of heat from electrical equipment or may be ignitible by abnormal operation or failure of electrical equipment. [*See Section 500-6(b) of NFPA 70, National Electrical Code*.]

Combustible Dust. Any finely divided solid material 420 microns or less in diameter (i.e., material passing through a U.S. No. 40 Standard Sieve) that presents a fire or explosion hazard when dispersed and ignites in air or other gaseous oxidizer.

Combustible Liquid. A liquid having a flash point at or above 100°F (37.8°C). Combustible liquids are subdivided as follows:

Class II liquids are those having flash points at or above 100°F (37.8°C) and below 140°F (60°C).

Class IIIA liquids are those having flash points at or above 140°F (60°C) and below 200°F (93.4°C).

Class IIIB liquids are those having flash points at or above 200°F (93.4°C).

(*See NFPA 321*, *Standard on Basic Classification of Flammable and Combustible Liquids*.)

Electrical Resistivity. A property of a dust that is determined by the test procedure described in Chapter 3 of *Test Equipment for Use in Determining Classification of Combustible Dusts*, NMAB 353-2.

NOTE: Metal dusts are to be considered conductive if the resistivity of the solid material from which the dust is formed has a value less than 10^5 ohm-cm.

Explosion Severity. A measure of the damage potential of the energy released by a dust explosion. (*See Section 3-3*.)

Flammable Liquid. A liquid having a flash point below 100°F (37.8°C) and having a vapor pressure not exceeding 40 psia at 100°F (37.8°C). Flammable liquids are subdivided as follows:

Class IA liquids are those having flash points below 73°F (22.8°C) and having boiling points below 100°F (37.8°C).

Class IB liquids are those having flash points below 73°F (22.8°C) and having boiling points at or above 100°F (37.8°C).

Class IC liquids are those having flash points at or above 73°F (22.8°C) and below 100°F (37.8°C).

(*See NFPA 321*, *Standard on Basic Classification of Flammable and Combustible Liquids*.)

Flash Point. The minimum temperature at which a liquid gives off vapor in sufficient concentration to form an ignitible mixture with air near the surface of the liquid, as specified by test. (*See NFPA 321*, *Standard on Basic Classification of Flammable and Combustible Liquids*.)

Hybrid Dust. A mixture of a dust with one or more flammable gases or vapors.

Ignition Sensitivity. A measure of the ease by which a cloud of combustible dust may be ignited. (*See Section 3-3*.)

Labeled. Equipment or materials to which has been attached a label, symbol or other identifying mark of an organization acceptable to the "authority having jurisdiction" and concerned with product evaluation, that maintains periodic inspection of production of labeled equipment or materials and by whose labeling the manufacturer indicates compliance with appropriate standards or performance in a specified manner.

Listed. Equipment or materials included in a list published by an organization acceptable to the "authority having jurisdiction" and concerned with product evaluation, that maintains periodic inspection of production of listed equipment or materials and whose listing states either that the equipment or material meets appropriate standards or has been tested and found suitable for use in a specified manner.

NOTE: The means for identifying listed equipment may vary for each organization concerned with product evaluation, some of which do not recognize equipment as listed unless it is also labeled. The "authority having jurisdiction" should utilize the system employed by the listing organization to identify a listed product.

Chapter 2 Class I Materials — Gases and Vapors

2-1

Articles 500 and 501 of NFPA 70, *National Electrical Code*, provide guidance for the use of electrical equipment in Class I locations (i.e., those made hazardous by flammable gases or vapors). Normally, the criteria for a Class I, Division 1 or Class I, Division 2 location, as specified in NFPA 70, *National Electrical Code*, must also be met. However, the mere presence of a flammable gas or vapor in an area does not necessarily require special electrical equipment for that area. For example, there are areas where a Division 2 condition may exist and sources of ignition, which cannot be modified because of process constraints, are normally present. Examples of such cases are open flames and exposed equipment surfaces with temperatures above the autoignition temperatures of the materials being handled. Also, there are materials that ignite spontaneously on contact with air. Special electrical equipment would not prevent ignition by those other sources.

2-2

The materials and their group classifications listed in Tables 2-3, 2-4, and 2-5 have been selected from *Matrix of Combustion-Relevant Properties and Classification of Gases, Vapors, and Selected Solids*, NMAB 353-1, published by the National Academy of Sciences. Those materials whose group classifications are marked with asterisks were previously assigned group classifications based on tests conducted in the Westerberg Apparatus at Underwriters Laboratories Inc. (*See "An Investigation of Fifteen Flammable Gases or Vapors with Respect to Explosion-Proof Electrical Equipment," UL Bulletin of Research No. 58 and subsequent Bulletins Nos. 58A and 58B.*) All other materials were assigned group classifications based on analogy with tested materials and on chemical structure. While the classifications of these latter materials represent the best judgment of two groups of experts, it is conceivable that the group classification of any particular untested material may be incorrect. In certain instances, therefore, it may be advisable to submit an un- tested material to a qualified testing laboratory for verification of the assigned group classification.

2-3

Table 2-3 lists those materials that are either flammable gases or vapors of flammable liquids as defined by NFPA 321, *Standard on Basic Classification of Flammable and Combustible Liquids*. In general, these gases or vapors form ignitible or explosive mixtures with air at ambient temperatures. Thus, special electrical equipment is normally required. (*See Section 2-1 for exceptions and mitigating circumstances*.)

Table 2-3

Group Classification and Autoignition Temperature (AIT) of Selected Flammable Gases and Vapors of Liquids Having Flash Points Below 100°F (37.8°C)

		AIT	
Material	**Group**	**°F**	**°C**
Acetaldehyde	C*	347	175
Acetone	D*	869	465
Acetonitrile	D	975	524
Acetylene	A*	581	305
Acrolein (inhibited)	B(C)*	455	235

Acrylonitrile	D*	898	481
Allyl Alcohol	C*	713	378
Allyl Chloride	D	905	485
Ammonia	D*[2]	928	498
n-Amyl Acetate	D	680	360
sec-Amyl Acetate	D	–	–
Benzene	D*	928	498
1,3-Butadiene	B(D)*[1]	788	420
Butane	D*	550	288
1-Butanol	D*	650	343
2-Butanol	D*	761	405
n-Butyl Acetate	D*	790	421
iso-Butyl Acetate	D*	790	421
sec-Butyl Acetate	D	–	–
Butylamine	D	594	312
Butylene	D	725	385
Butyl Mercaptan	C	–	–
n-Butyraldehyde	C*	425	218
Carbon Disulfide	-*[3]	194	90
Carbon Monoxide	C*	1128	609
Chlorobenzene	D	1099	593
Chloroprene	D	–	–
Crotonaldehyde	C*	450	232
Cumene	D	795	424
Cyclohexane	D	473	245
Cyclohexene	D	471	244
Cyclopropane	D*	938	503
1,1-Dichloroethane	D	820	438
1,2-Dichloroethylene	D	860	460
1,3-Dichloropropene	D	–	–
Dicyclopentadiene	C	937	503

Diethyl Ether	C*	320	160
Diethylamine	C*	594	312
Di-isobutylene	D*	736	391
Di-isopropylamine	C	600	316
Dimethylamine	C	752	400
1,4-Dioxane	C	356	180
Di-n-propylamine	C	570	299
Epichlorohydrin	C*	772	411
Ethane	D*	882	472
Ethanol	D*	685	363
Ethyl Acetate	D*	800	427
Ethyl Acrylate(inhibited)	D*	702	372
Ethylamine	D*	725	385
Ethyl Benzene	D	810	432
Ethyl Chloride	D	966	519
Ethylene	C*	842	450
Ethylenediamine	D*	725	385
Ethylene Dichloride	D*	775	413
Ethylenimine	C*	608	320
Ethylene Oxide	B(C)*[1]	804	429
Ethyl Formate	D	851	455
Ethyl Mercaptan	C*	572	300
n-Ethyl Morpholine	C	–	–
Formaldehyde (Gas)	B	795	429
Fuel and Combustible Process Gas (containing more than 30 percent H_2 by volume)	B**	–	–
Gasoline	D*	536-880	280-471
Heptane	D*	399	204
Heptene	D	500	260
Hexane	D*	437	225
2-Hexanone	D	795	424

Hexenes	D	473	245
Hydrogen	B*	968	520
Hydrogen Cyanide	C*	1000	538
Hydrogen Selenide	C	–	–
Hydrogen Sulfide	C*	500	260
Isoamyl Acetate	D	680	360
Isobutyl Acrylate	D	800	427
Isobutyraldehyde	C	385	196
Isoprene	D*	428	220
Isopropyl Acetate	D	860	460
Isopropylamine	D	756	402
Isopropyl Ether	D*	830	443
Isopropyl Glycidyl Ether	C	–	–
Liquefied Petroleum Gas	D	761-842	405-450
Manufactured Gas (see Fuel and Combustible Process Gas)	–	–	–
Mesityl Oxide	D*	652	344
Methane	D*	999	630
Methanol	D*	725	385
Methyl Acetate	D	850	454
Methylacetylene	C*	–	–
Methylacetylene-Propadiene (stabilized)	C	–	–
Methyl Acrylate	D	875	468
Methylamine	D	806	430
Methylcyclohexane	D	482	250
Methyl Ether	C*	662	350
Methyl Ethyl Ketone	D*	759	404
Methyl Formal	C*	460	238
Methyl Formate	D	840	449
Methyl Isobutyl Ketone	D*	840	440
Methyl Isocyanate	D	994	534

Methyl Mercaptan	C	–	–
Methyl Methacrylate	D	792	422
2-Met 2-M-1-opanol	D*	780	416
2-Met 2-M-2-opanol	D*	892	478
Monomethyl Hydrazine	C	382	194
Naphtha (Petroleum)	D*[4]	550	288
Nitroethane	C	778	414
Nitromethane	C	785	418
1-Nitropropane	C	789	421
2-Nitropropane	C*	802	428
Nonane	D	401	205
Nonene	D	–	–
Octane	D*	403	206
Octene	D	446	230
Pentane	D*	470	243
1-Pentanol	D*	572	300
2-Pentanone	D	846	452
1-Pentene	D	527	275
Propane	D*	842	450
1-Propanol	D*	775	413
2-Propanol	D*	750	399
Propionaldehyde	C	405	207
n-Propyl Acetate	D	842	450
Propylene	D*	851	455
Propylene Dichloride	D	1035	557
Propylene Oxide	B(C)*[1]	840	449
n-Propyl Ether	C*	419	215
Propyl Nitrate	B*	347	175

Pyridine	D*	900	482
Styrene	D*	914	490
Tetrahydrofuran	C*	610	321
Toluene	D*	896	480
Triethylamine	C*	–	–
Turpentine	D	488	253
Unsymmetrical Dimethyl Hydrazine (UDMH)	C*	480	249
Valeraldehyde	C	432	222
Vinyl Acetate	D*	756	402
Vinyl Chloride	D*	882	472
Vinylidene Chloride	D	1058	570
Xylenes	D*	867-984	464-529

Notes To Table 2-3

* Material has been classified by test.

** Fuel and process gas mixtures found by test not to present hazards similar to those of hydrogen may be grouped based on the test results.

[1]If equipment is isolated by sealing all conduit $^1/_2$ in. or larger, in accordance with Section 501-5(a) of NFPA 70, *National Electrical Code*, equipment for the group classification shown in parentheses is permitted.

[2]For classification of areas involving Ammonia, see *Safety Code for Mechanical Refrigeration*, ANSI/ASHRAE 15, and *Safety Requirements for the Storage and Handling of Anhydrous Ammonia*, ANSI/CGA G2.1.

[3]Certain chemicals may have characteristics that require safeguards beyond those required for any of the above groups. Carbon disulfide is one of these chemicals because of its low autoignition temperature and the small joint clearance to arrest its flame propagation.

[4]Petroleum Naphtha is a saturated hydrocarbon mixture whose boiling range is 20° to 135°C. It is also known as benzine, ligroin, petroleum ether, and naphtha.

References: Autoignition temperatures listed above are the lowest value for each material as listed in NFPA 325M, *Fire Hazard Properties of Flammable Liquids, Gases, and Volatile Solids*, or as reported in an article by Hilado, C. J. and Clark, S. W., in *Chemical Engineering*, September 4, 1972.

2-4

Table 2-4 lists vapors of Class II combustible liquids as defined by NFPA 321, *Standard on*

Basic Classification of Flammable and Combustible Liquids. In general, these materials do not form flammable mixtures with air at ambient temperatures unless heated above their flash points. Special electrical equipment is normally required only under such circumstances. (*See 1-1.3 of NFPA 30, Flammable and Combustible Liquids Code*.)

Table 2-4 Group Classification and Autoignition Temperature (AIT) of Vapors of Selected Liquids Having Flash Points 100°F (37.8°C) or Greater, but Less than 140°F (60°C)

NOTE: In accordance with 1-1.3 of NFPA 30, *Flammable and Combustible Liquids Code*, special electrical equipment is required only where these materials are stored or handled at temperatures above their flash points.

		AIT	
Material	**Group**	**°F**	**°C**
Acetic Acid	D*	867	464
Acetic Anhydride	D	600	316
Acrylic Acid	D	820	438
Allyl Glycidyl Ether	B(C)[1]		
t-Butyl Acetate	D	–	–
n-Butyl Acrylate (inhibited)	D	559	293
n-Butyl Glycidyl Ether	B(C)[1]	–	–
Cyclohexanone	D	473	245
p-Cymene	D	817	436
Decene	D	455	235
Diethyl Benzene	D	743-842	395-450
Di-isobutyl Ketone	D	745	396
Dimethyl Formamide	D	833	455
Dipentene	D	458	237
Ethyl sec-Amyl Ketone	D	–	–
Ethyl Butanol	D	–	–
Ethyl Butyl Ketone	D	–	–
Ethylene Glycol Monoethyl Ether	C	455	235
Ethylene Glycol Monoethyl	C	715	379

Ether Acetate			
Ethylene Glycol Monomethyl Ether	D	545	285
2-Ethylhexaldehyde	C	375	191
Ethyl Silicate	D	–	–
Formic Acid (90%)	D	813	434
Fuel Oils	D	410-765	210-407
sec-Hexyl Acetate	D	–	–
Hydrazine	C	74-518	23-270
Isoamyl Alcohol	D	662	350
Iso-octyl Aldehyde	C	387	197
Kerosene	D	410	210
Methyl Amyl Alcohol	D	–	–
Methyl n-Amyl Ketone	D	740	393
o-Methylcyclohexanone	D	–	–
alpha-Methyl Styrene	D	1066	574
Morpholine	C*	590	310
Naphtha (Coal Tar)	D	531	277
Propionic Acid	D	870	466
Tetramethyl Lead	C	–	–
Tripropylamine	D	–	–

Notes to Table 2-4

* Material has been classified by test.

[1]If equipment is isolated by sealing all conduit $^1/_2$ in. or larger, in accordance with Section 501-5(a) of NFPA 70, *National Electrical Code,* equipment for the group classification shown in parentheses is permitted.

References: Autoignition temperatures listed above are the lowest value for each material as listed in NFPA 325M, *Fire Hazard Properties of Flammable Liquids, Gases, and Volatile Solids*, or as reported in an article by Hilado, C. J. and Clark, S. W., in *Chemical Engineering*, September 4, 1972.

2-5

Table 2-5 lists vapors of Class IIIA combustible liquids as defined by NFPA 321, *Standard on Basic Classification of Flammable and Combustible Liquids*. These materials do not form flammable mixtures with air at ambient temperatures unless they are heated above their flash points. Furthermore, the vapors from such heated liquids cool rapidly in air. Special electrical equipment is required only in the space in which the temperature of the vapor is actually above the flashpoint of the liquid or in the space in which mists may condense in ignitible concentrations as vapors cool. (*See 1-1.3 of NFPA 30*.)

Table 2-5 Group Classification and Autoignition Temperature (AIT) of Vapors of Selected Liquids Having Flash Points 140°F (60°C) or Greater, but Less than 200°F (93.3°C)

NOTE: In accordance with 1-1.3 of NFPA 30, *Flammable and Combustible Liquids Code*, special electrical equipment is required only where these materials are stored or handled at temperatures above their flash points. Vapors of such heated liquids cool rapidly in air, limiting the area of concern to that space in which the temperature of the vapors remains above the flash point of the liquid.

		AIT	
Material	**Group**	**°F**	**°C**
Acetone Cyanohydrin	D	1270	688
Adiponitrile	D		
Aniline	D	1139	615
Benzyl Chloride	D	1085	585
n-Butyl Formal	C		
t-Butyl Toluene	D		
n-Butyric Acid	D	830	443
Chloroacetaldehyde	C		
1-Chl 1-C-1-tropropane	C		
Cresol	D	1038-1110	559-599
Cyclohexanol	D	572	300
n-Decaldehyde	C		
n-Decanol	D	550	288
Diacetone Alcohol	D	1118	603
o-Dichlorobenzene	D	1198	647
1,1-Dichloro-1-Nitroethane	C		
Diethylaminoethanol	C		
Diethylene Glycol Monobutyl Ether	C	442	228

Diethylene Glycol Monomethyl Ether	C	465	241
Ethylene Chlorohydrin	D	797	425
N-N-Dimethyl Aniline	C	700	371
Dimethyl Sulfate	D	370	188
Dipropylene Glycol Methyl Ether	C		
Dodecene	D	491	255
Ethylene Glycol Monobutyl Ether	C	460	238
Ethylene Glycol Monobutyl Ether Acetate	C	645	340
2-Ethyl Hexanol	D	448	231
2-Ethyl Hexyl Acrylate	D	485	252
2-E R2-E-3-opyl Acrolein	C		
Furfural	C	600	316
Furfuryl Alcohol	C	915	490
Hexanol	D		
Isodecaldehyde	C		
Iso-octyl Alcohol	D		
Isophorone	D	860	460
Methylcyclohexanol	D	565	296
2-Met 2-M-5-hyl Pyridine	D		
Monoethanolamine	D	770	410
Monoisopropanolamine	D	705	374
Monomethyl Aniline	C	900	482
Nitrobenzene	D	900	482
Nonyl Alcohol	D		
n-Octyl Alcohol	D		
Phenylhydrazine	D		
Propiolactone	D		
Propionic Anhydride	D	545	285
Tetrahydronaphthalene	D	725	385
Tridecene	D		

Triethylbenzene	D		
Undecene	D		
Vinyl Toluene	D	921	494

Reference: Autoignition temperatures listed above are the lowest value for each material as listed in NFPA 325M, *Fire Hazard Properties of Flammable Liquids, Gases, and Volatile Solids*, or as reported in an article by Hilado, C. J. and Clark, S. W., in *Chemical Engineering*, September 4, 1972.

2-6

Experience has shown that Class IIIB combustible liquids are seldom ignited by properly installed and maintained general purpose electrical equipment. Therefore, Class IIIB liquids are not included in the tables.

2-7

Appendix B lists references that deal with the testing of various characteristics of flammable and combustible gases and vapors.

Chapter 3 Class II Materials — Dusts

3-1*

Articles 500 and 502 of NFPA 70, *National Electrical Code*, provide guidance for the use of electrical equipment in Class II locations (i.e., those made hazardous by combustible dusts). Normally the criteria for a Class II, Division 1 or Class II, Division 2 location, as specified in NFPA 70, *National Electrical Code*, must be met. However, the mere presence of a combustible dust in an area does not necessarily require special electrical equipment for that area. For example, if ignition sources are normally present, special electrical equipment would not prevent ignition by those sources. On the other hand, materials that are normally not considered combustible may have dusts that are explosive or may, as in the form of a hybrid dust, be combustible. The presence of flammable gas(es) or vapors, even at concentrations less than their lower flammable limit (LFL), will add to the violence of the dust-air combustion and may require electrical equipment that is suitable for simultaneous exposure to both Class I and Class II locations. Additionally, the dusts from other materials may exhibit characteristics that require special electrical equipment for that area.

3-2

The materials, and their group classifications, listed in Tables 3-4, 3-5, and 3-6, have been taken from *Classification of Combustible Dusts in Accordance with the National Electrical Code*, NMAB 353-3, published by the National Academy of Sciences. Dusts having ignition sensitivities equal to or greater than 0.2 or explosion severities equal to or greater than 0.5 are listed. Dusts whose explosibility parameters fall below these limits are not generally considered to be significant explosion hazards and are, therefore, not included in these tables. Selection of electrical equipment for dusts that sublime or melt below the operating temperature of the equipment requires additional consideration of the properties of the specific dust. Electrical equipment evaluated and found acceptable for use in the presence of dusts may not be acceptable when exposed to molten material.

3-3

The U.S. Bureau of Mines has defined ignition sensitivity and explosion severity as follows:

$$\text{Explosive Severity} = \frac{(P_{max} \times P)_2}{(P_{max} \times P)_1}$$

$$\text{Ignition Sensitivity} = \frac{(T_c \times E \times M_c)_1}{(T_c \times E \times M_c)_2}$$

where P_{max}	=	Maximum Explosive Pressure;
P	=	Maximum Rate of Pressure Rise;
T_c	=	Minimum Ignition Temperature;
E	=	Minimum Ignition Energy;
M_c	=	Minimum Explosive Concentration.

Subscript 1 refers to the appropriate values for Pittsburg seam coal, the standard dust used by the U.S. Bureau of Mines.

Subscript 2 refers to the values for the specific dust in question.

NOTE: Units must be consistent in both numerators and denominators.

3-4

Table 3-4 lists selected metallic dusts that are classified as Group E.

Table 3-4 Selected Metallic Dusts Classified as Group E — Ignition Sensitivity Equal to or Greater than 0.2; Explosion Severity Equal to or Greater than 0.5

	Minimum Cloud or Layer Ignition Temp.[1]		
Material[2]	**°F**		**°C**
Aluminum, atomized collector fines	1022	Cl	550
Aluminum, A422 flake	608		320
Aluminum — cobalt alloy (60-40)	1058		570
Aluminum — copper alloy (50-50)	1526		830
Aluminum — lithium alloy (15% Li)	752		400

Aluminum — magnesium alloy (Dowmetal)	806	Cl	430
Aluminum — nickel alloy (58-42)	1004		540
Aluminum — silicon alloy (12% Si)	1238	NL	670
Boron, commercial-amorphous (85% B)	752		400
Calcium Silicide	1004		540
Chromium, (97%) electrolytic, milled	752		400
Ferromanganese, medium carbon	554		290
Ferrosilicon (88%, 9% Fe)	1472		800
Ferrotitanium (19% Ti, 74.1% Fe, 0.06% C)	698	Cl	370
Iron, 98%, H_2 reduced	554		290
Iron, 99%, Carbonyl	590		310
Magnesium, Grade B, milled	806		430
Manganese	464		240
Tantalum	572		300
Thorium, 1.2% 0_2	518	Cl	270
Tin, 96%, atomized (2% Pb)	806		430
Titanium, 99%	626	Cl	330
Titanium Hydride (95% Ti, 3.8% H_2)	896	Cl	480
Vanadium, 86.4%	914		490
Zirconium Hydride (93.6% Zr, 2.1% H_2)	518		270

Notes to Table 3-4

[1]Normally, the minimum ignition temperature of a layer of a specific dust is lower than the minimum ignition temperature of a cloud of that dust. Since this is not universally true, the lower of the two minimum ignition temperatures is listed. If no symbol appears between the two temperature columns, then the layer ignition temperature is shown. “Cl” means the cloud ignition temperature is shown. “NL” means that no layer ignition temperature is available, and

the cloud ignition temperature is shown.

[2]Certain metal dusts may have characteristics that require safeguards beyond those required for atmospheres containing the dusts of aluminum, magnesium, and their commercial alloys. For example, zirconium, thorium, and uranium dusts have extremely low ignition temperatures (as low as 20°C) and minimum ignition energies lower than any material classified in any of the Class I or Class II groups.

3-5

Table 3-5 lists selected carbonaceous dusts that are classified as Group F.

Table 3-5 Selected Carbonaceous Dusts Classified as Group F — Ignition Sensitivity Equal to or Greater than 0.2; Explosion Severity Equal to or Greater than 0.5

	Minimum Cloud or Layer Ignition Temp.[1]		
Material	**°F**		**°C**
Asphalt (Blown Petroleum Resin)	950	Cl	510
Charcoal	356		180
Coal, Kentucky Bituminous	356		180
Coal, Pittsburgh Experimental	338		170
Coal, Wyoming			
Gilsonite	932		500
Lignite, California	356		180
Pitch, Coal Tar	1310	NL	710
Pitch, Petroleum	1166	NL	630
Shale, Oil	–		–

Note to Table 3-5

[1]Normally, the minimum ignition temperature of a layer of a specific dust is lower than the minimum ignition temperature of a cloud of that dust. Since this is not universally true, the lower of the two minimum ignition temperatures is listed. If no symbol appears between the two temperature columns, then the layer ignition temperature is shown. “Cl” means the cloud ignition temperature is shown. “NL” means that no layer ignition temperature is available, and the cloud ignition temperature is shown.

3-6

Table 3-6 lists selected other dusts that are classified as Group G.

Table 3-6

Selected Other Dusts Classified as Group G – Ignition Sensitivity Equal to or Greater than 0.2; Explosion Severity Equal to or Greater than 0.5

	Minimum Cloud or Layer Ignition Temp.[1]		
Material	**°F**		**°C**
AGRICULTURAL DUSTS			
Alfalfa Meal	392		200
Almond Shell	392		200
Apricot Pit	446		230
Cellulose	500		260
Cherry Pit	428		220
Cinnamon	446		230
Citrus Peel	518		270
Cocoa Bean Shell	698		370
Cocoa, natural, 19% fat	464		240
Coconut Shell	428		220
Corn	482		250
Corncob Grit	464		240
Corn Dextrine	698		370
Cornstarch, commercial	626		330
Cornstarch, modified	392		200
Cork	410		210
Cottonseed Meal	392		200
Cube Root, South Amer.	446		230
Flax Shive	446		230
Garlic, dehydrated	680	NL	360
Guar Seed	932	NL	500
Gum, Arabic	500		260
Gum, Karaya	464		240
Gum, Manila (copal)	680	Cl	360
Gum, Tragacanth	500		260
Hemp Hurd	428		220
Lycopodium	590		310
Malt Barley	482		250
Milk, Skimmed	392		200

Pea Flour	500		260
Peach Pit Shell	410		210
Peanut Hull	410		210
Peat, Sphagnum	464		240
Pecan Nut Shell	410		210
Pectin	392		200
Potato Starch, Dextrinated	824	NL	440
Pyrethrum	410		210
Rauwolfia Vomitoria Root	446		230
Rice	428		220
Rice Bran	914	NL	490
Rice Hull	428		220
Safflower Meal	410		210
Soy Flour	374		190
Soy Protein	500		260
Sucrose	662	Cl	350
Sugar, Powdered	698	Cl	370
Tung, Kernels, Oil-Free	464		240
Walnut Shell, Black	428		220
Wheat	428		220
Wheat Flour	680		360
Wheat Gluten, gum	968	NL	520
Wheat Starch	716	NL	380
Wheat Straw	428		220
Woodbark, Ground	482		250
Wood Flour	500		260
Yeast, Torula	500		260
CHEMICALS			
Acetoacetanilide	824	M	440
Acetoacet-p-phenetidide	1040	NL	560
Adipic Acid	1022	M	550
Anthranilic Acid	1076	M	580

Aryl-nitrosomethylamide	914	NL	490
Azelaic Acid	1130	M	610
2,2-Azo-bis-butyronitrile	662		350
Benzoic Acid	824	M	440
Benzotriazole	824	M	440
Bisphenol-A	1058	M	570
Chloroacetoacetanilide	1184	M	640
Diallyl Phthalate	896	M	480
Dicumyl Peroxide (suspended on $CaC0_3$), 40-60	356		180
Dicyclopentadiene Dioxide	788	NL	420
Dihydroacetic Acid	806	NL	430
Dimethyl Isophthalate	1076	M	580
Dimethyl Terephthalate	1058	M	570
3,5 - Dinitrobenzoic Acid	860	NL	460
Dinitrotoluamide	932	NL	500
Diphenyl	1166	M	630
Ditertiary Butyl Paracresol	878	NL	470
Ethyl Hydroxyethyl Cellulose	734	NL	390
Fumaric Acid	968	M	520
Hexamethylene Tetramine	770	S	410
Hydroxyethyl Cellulose	770	NL	410
Isotoic Anhydride	1292	NL	700
Methionine	680		360
Nitrosoamine	518	NL	270
Para-oxy-benzaldehyde	716	Cl	380
Paraphenylene Diamine	1148	M	620
Paratertiary Butyl Benzoic Acid	1040	M	560
Pentaerythritol	752	M	400
Phenylbetanaphthylamine	1256	NL	680
Phthalic Anydride	1202	M	650
Phthalimide	1166	M	630

Salicylanilide	1130	M	610
Sorbic Acid	860		460
Stearic Acid, Aluminum Salt	572		300
Stearic Acid, Zinc Salt	950	M	510
Sulfur	428		220
Terephthalic Acid	1256	NL	680
DRUGS			
2-Acetylamino-5-nitrothiazole	842		450
2-Am 2-A-5-trothiazole	860		460
Aspirin	1220	M	660
Gulasonic Acid, Diacetone	788	NL	420
Mannitol	860	M	460
Nitropyridone	806	M	430
l-Sorbose	698	M	370
Vitamin B1, mononitrate	680	NL	360
Vitamin C (Ascorbic Acid)	536		280
DYES, PIGMENTS,			
INTERMEDIATES			
Beta-naphthalene-azo-Dimethylaniline	347		175
Green Base Harmon Dye	347		175
Red Dye Intermediate	347		175
Violet 200 Dye	347		175
PESTICIDES			
Benzethonium Chloride	716	Cl	380
Bis(2-Hydroxy-5-chlorophenyl) methane	1058	NL	570
Crag No. 974	590	Cl	310
Dieldrin (20%)	1022	NL	550
2, 6-Ditertiary-butyl-paracresol	788	NL	420
Dithane	356		180
Ferbam	302		150

Manganese Vancide	248		120
Sevin	284		140
α, α -Trithiobis (N,N-Dimethylthio-formamide)	446		230
THERMOPLASTIC RESINS			
AND MOLDING COM-			
POUNDS			
<u>Acetal Resins</u>			
Acetal, Linear (Polyformaldehyde)	824	NL	440
<u>Acrylic Resins</u>			
Acrylamide Polymer	464		240
Acrylonitrile Polymer	860		460
Acrylonitrile - Vinyl			
Pyridine Copolymer	464		240
Acrylonitrile-Vinyl Chloride-Vinylidene Chloride Copolymer (70-20-10)	410		210
Methyl Methacrylate Polymer	824	NL	440
Methyl Methacrylate - Ethyl Acrylate Copolymer	896	NL	480
Methyl Methacrylate- Ethyl Acrylate- Styrene Copolymer	824	NL	440
Methyl Methacrylate- Styrene-	896	NL	480
Butadiene-Acrylonitrile Copolymer			
Methacrylic Acid			
Polymer	554		290
<u>Cellulosic Resins</u>			
Cellulose Acetate	644		340
Cellulose Triacetate	806	NL	430
Cellulose Acetate Butyrate	698	NL	370
Cellulose Propionate	860	NL	460
Ethyl Cellulose	608	Cl	320
Methyl Cellulose	644		340

Carboxymethyl Cellulose	554		290	
Hydroxyethyl Cellulose	644		340	
Chlorinated Polyether Resins				
Chlorinated Polyether Alcohol	860		460	
Nylon (Polyamide) Resins				
Nylon Polymer (Polyhexa-methylene Adipamide)	806		430	
Polycarbonate Resins				
Polycarbonate	1310	NL	710	
Polyethylene Resins				
Polyethylene, High Pressure Process	716		380	
Polyethylene, Low Pressure Process	788	NL	420	
Polyethylene Wax	752	NL	400	
Polymethylene Resins				
Carboxypolymethylene	968	NL	520	
Polypropylene Resins				
Polypropylene (No Antioxidant)	788	NL	420	
Rayon Resins				
Rayon (Viscose) Flock	482		250	
Styrene Resins				
Polystyrene Molding Cmpd.	1040	NL	560	
Polystyrene Latex	932		500	
Styrene-Acrylonitrile (70-30)		932	NL	500
Styrene-Butadiene Latex(> 75% Styrene; Alum Coagulated)	824	NL	440	
Vinyl Resins				

Polyvinyl Acetate	1022	NL	550	
Polyvinyl Acetate/Alcohol	824		440	
Polyvinyl Butyral	734	NL	390	
Vinyl Chloride - Acrylonitrile Copolymer		878		470
Polyvinyl Chloride - Dioctyl Phthalate Mixture	608	NL	320	
Vinyl Toluene - Acrylonitrile Butadiene Copolymer		936	NL	530
THERMOSETTING				
RESINS AND MOLDING				
COMPOUNDS				
<u>Allyl Resins</u>				
Allyl Alcohol Derivative (CR-39)	932	NL	500	
<u>Amino Resins</u>				
Urea Formaldehyde Molding Compound		860	NL	460
Urea Formaldehyde - Phenol Formaldehyde Molding Compound (Wood Flour Filler)	464		240	
<u>Epoxy Resins</u>				
Epoxy	1004	NL	540	
Epoxy - Bisphenol A	950	NL	510	
Phenol Furfural	590		310	
<u>Phenolic Resins</u>				
Phenol Formaldehyde	1076	NL	580	
Phenol Formaldehyde Molding Cmpd (Wood Flour Filler)		932	NL	500
Phenol Formaldehyde, Polyalkylene- Polyamine	554		290	

Modified			
<u>Polyester Resins</u>			
Polyethylene Terephthalate	932	NL	500
Styrene Modified Polyester-Glass Fiber Mixture	680		360
<u>Polyurethane Resins</u>			
Polyurethane Foam, No Fire Retardant	824		440
Polyurethane Foam, Fire Retardant	734		390
SPECIAL RESINS AND MOLDING COMPOUNDS			
Alkyl Ketone Dimer Sizing Compound	320		160
Cashew Oil, Phenolic, Hard	356		180
Chlorinated Phenol	1058	NL	570
Coumarone-Indene, Hard	968	NL	520
Ethylene Oxide Polymer	662	NL	350
Ethylene-Maleic Anhydride Copolymer	1004	NL	540
Lignin, Hydrolized, Wood-Type, Fines	842	NL	450
Petrin Acrylate Monomer	428	NL	220
Petroleum Resin (Blown Asphalt)	932		500
Rosin, DK	734	NL	390
Rubber, Crude, Hard	662	NL	350
Rubber, Synthetic, Hard (33% S)	608	NL	320
Shellac	752	NL	400
Sodium Resinate	428		220

Styrene — Maleic Anhydride Copolymer	878	Cl	470

Note to Table 3-6

[1]Normally, the minimum ignition temperature of a layer of a specific dust is lower than the minimum ignition temperature of a cloud of that dust. Since this is not universally true, the lower of the two minimum ignition temperatures is listed. If no symbol appears between the two temperature columns, then the layer ignition temperature is shown. “Cl” means the cloud ignition temperature is shown. “NL” means that no layer ignition temperature is available, and the cloud ignition temperature is shown. “M” signifies that the dust layer melts before it ignites; the cloud ignition temperature is shown. “S” signifies that the dust layer sublimes before it ignites; the cloud ignition temperature is shown.

3-7* Dust Groupings.

Combustible dusts may be divided into the following groupings:

Group E: Atmospheres containing combustible metal dusts, including aluminum, magnesium, and their commercial alloys, or other combustible dusts whose particle size, abrasiveness, and conductivity present similar hazards in the use of electrical equipment. (See hybrid dust.)

Group F: Atmospheres containing combustible carbonaceous dusts, including carbon black, charcoal, coal, or coke dust, that have more than 8 percent total entrapped volatiles (see ASTM D3175-89 for coal and coke dusts), or that have been sensitized by other materials so that they present an explosion hazard. (See hybrid dust.)

Group G: Atmospheres containing other combustible dusts, including flour, grain, wood flour, plastic, and chemicals. (See hybrid dust.)

For purposes of classification, only Group E dusts are considered conductive.

3-8

Appendix B lists references that deal with the testing of various characteristics of combustible dusts.

Chapter 4 Referenced Publications

4-1

The following documents or portions thereof are referenced within this manual and should be considered part of the recommendations of this document. The edition indicated for each reference is the current edition as of the date of the NFPA issuance of this document.

4-1.1 NFPA Publications.

National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.

NFPA 30, *Flammable and Combustible Liquids Code*, 1990 edition

NFPA 70, *National Electrical Code*, 1990 edition

NFPA 321, *Standard on Basic Classification of Flammable and Combustible Liquids*, 1991 edition

NFPA 325M, *Fire Hazard Properties of Flammable Liquids, Gases, and Volatile Solids*, 1991 edition

Appendix A

This Appendix is not a part of the recommendations of this NFPA document, but is included for information purposes only.

A-3-1 Hybrid Dusts.

The presence of flammable gas in a combustible dust cloud drastically reduces the ignition energy. The flammable gas need not be present in amounts sufficient to reach the lower flammable limit (considering the gas phase alone) to exhibit this phenomenon.

Similarly, the rate of pressure rise when a cloud of dust, gas, and air ignites is higher than would normally be expected. This situation is encountered in certain industrial operations, such as fluidized bed driers and pneumatic conveying systems for plastic dusts from polymerization processes where a volatile solvent is used. In such cases, electrical equipment should be specified that is suitable for simultaneous exposure to both Class I and Class II locations and has safe operating temperatures.

A-3-7

Prior to the 1981 edition of NFPA 70, *National Electrical Code* (1978 and prior editions), all Group E (metal dusts such as aluminum, magnesium, and their commercial alloys) and Group F (carbonaceous dusts such as carbon black, charcoal, or coke dusts having more than 8 percent total volatile materials) were considered to be electrically conductive. As a result, areas containing Group E or Group F dusts were all classified Division 1, as required by the definition of a Class II, Division 1 location. It was only possible to have a Division 2 area for Group G dusts.

The 1984 edition eliminated Group F altogether. Carbonaceous dusts with resistivity of less than 10^5 ohm-cm were considered conductive and were classified as Group E. Carbonaceous dusts with resistivity of 10^5 ohm-cm or greater were considered nonconductive and were classified as Group G. This reclassification allowed the use of Group G, Division 2 electrical equipment for many carbonaceous materials.

The 1987 edition of the *National Electrical Code* reinstated Group F because the close tolerances in Group E motors necessary for metal dusts are unnecessary for conductive carbonaceous dusts, and the low temperature specifications in Group G equipment necessary for grain, flour, and some chemical dusts are unnecessary for nonconductive carbonaceous dusts. This imposed an unwarranted expense on users.

This change allowed the use of Group F, Division 2 electrical equipment for carbonaceous dust with a resistivity greater than 10^5 ohm-cm.

The problem with this work was that the resistivity value, a number that related to the dust's ability to conduct an electric current, was not a constant and varied considerably based on dust particle size and extent of oxidation, the moisture content, voltage applied, temperature, and test apparatus and technique. No standardized test method for the resistivity value considering long-term environmental effects has been developed. Finally, the resistivity value is not directly related to the explosion hazard.

Appendix B Bibliography

This Appendix is not a part of the recommendations of this NFPA document, but is included for information purposes only.

B-1 ASTM Publications.

American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103.

ASTM D56-87, *Standard Method of Test for Flash Point by the Tag Closed Tester*

ASTM D93-85, *Standard Method of Test for Flash Point by the Pensky-Martens Closed Tester*

ASTM D3278-82, *Standard Method of Tests for Flash Point of Liquids by Setaflash Closed Tester*

ASTM E659-78, *Test for Autoignition Temperature of Liquid Chemicals*

ASTM E681-85, *Test for Limits of Flammability of Chemicals*

ASTM E789-89, *Standard Test Method for Pressure and Rate of Pressure Rise for Dust Explosions in a Closed Vessel*

B-2 U.S. Bureau of Mines Publications.

U.S. Government Printing Office, Washington, DC 20402.

RI 5624, *Laboratory Equipment and Test Procedures for Evaluating Explosibility of Dusts*

RI 5753, *Explosibility of Agricultural Dusts*

RI 5971, *Explosibility of Dusts Used in the Plastics Industry*

RI 6516, *Explosibility of Metal Powders*

RI 6597, *Explosibility of Carbonaceous Dusts*

RI 7009, *Minimum Ignition Energy and Quenching Distance in Gaseous Mixture*

RI 7132, *Dust Explosibility of Chemicals, Drugs, Dyes, and Pesticides*

RI 7208, *Explosibility of Miscellaneous Dusts*

Appendix C Referenced Publications

C-1

The following documents or portions thereof are referenced within this manual for informational purposes only and thus should not be considered part of the recommendations of this document. The edition indicated for each reference is the current edition as of the date of the NFPA issuance of this document.

C-1.1 NFPA Publication.

National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.

NFPA 70, *National Electrical Code*, 1990 edition

C-1.2 National Academy of Sciences Publications.

National Materials Advisory Board of the National Academy of Sciences, 2101 Constitution Avenue, NW, Washington, DC 20418.

NMAB 353-1, *Matrix of Combustion—Relevant Properties and Classifications of Gases, Vapors, and Selected Solids*

NMAB 353-2, *Test Equipment for Use in Determining Classifications of Combustible Dusts*

NMAB 353-3, *Classification of Combustible Dusts in Accordance with the National Electrical Code*

C-1.3 UL Publications.

Underwriters Laboratories Inc., 333 Pfingsten Rd, Northbrook, IL 60062.

Technical Report No. 58-1993, *An Investigation of Flammable Gases or Vapors With Respect to Explosion-Proof Electrical Equipment.*

C-1.4 Other Publications.

ANSI/ASHRAE 15-1989, *Safety Code for Mechanical Refrigeration*, available from the American National Standards Institute, 1430 Broadway, New York, NY 10018.

ANSI/CGA G2.1-1989, *Safety Requirements for the Storage and Handling of Anhydrous Ammonia*, available from the American National Standards Institute, 1430 Broadway, New York, NY 10018.

ASTM D3175-89, *Standard Test Method for Volatile Matter in the Analysis Sample of Coal and Coke*, available from the American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103.

Hilado, C. J. and Clark, S. W., "Autoignition Temperatures of Organic Chemicals," *Chemical Engineering*, Sept. 4, 1972.

NFPA 498

1996 Edition

Standard for Safe Havens and Interchange Lots for Vehicles Transporting Explosives

1996 Edition

This edition of NFPA 498, *Standard for Safe Havens and Interchange Lots for Vehicles Transporting Explosives*, was prepared by the Technical Committee on Explosives and acted on by the National Fire Protection Association, Inc., at its Annual Meeting held May 20-23, 1996, in Boston, MA. It was issued by the Standards Council on July 18, 1996, with an effective date of August 9, 1996, and supersedes all previous editions.

This document has been submitted to ANSI for approval.

Origin and Development of NFPA 498

This standard was developed by the Technical Committee on Explosives to address the special requirements of motor vehicle terminals specifically designed to handle cargoes of explosive materials. It was tentatively adopted at the 1969 NFPA Annual Meeting and officially adopted at the 1970 NFPA Annual Meeting. Several amendments were adopted at the 1976 NFPA Annual Meeting and at the 1982 NFPA Annual Meeting. In 1986, 1990, and 1992, the document was reconfirmed.

Formerly titled "Explosives Motor Vehicle Terminals," the 1996 edition of NFPA 498 is a complete revision.

The new standard more completely addresses the fire, theft, and explosion hazards that exist when explosive materials are present in parked vehicles in safe havens and in explosives interchange lots.

NOTICE

Following the issuance of this edition of NFPA 498, Standard for Safe Havens and Interchange Lots for Vehicles Transporting Explosives, by the NFPA Standards Council, an appeal was filed with the NFPA Board of Directors.

The appeal requests that the Board of Directors reverse the Standards Council decision and issue the 1996 edition of NFPA 498 with the inclusion of public comments 498-11 (1-4), 498-12 (1-4, 2-1, 3-1), 498-13 (2-1.3, 2-1.6, 3-2.7), 498-16 (2-2), 498-24 (2-6, 3-6), and 498-31 (4-1.1). At the time of printing, this appeal was under consideration by the NFPA Board of Directors.

NFPA will announce the disposition of the appeal when it has been determined. Anyone wishing to receive the disposition of the appeal should notify in writing the Secretary, Standards Council, NFPA, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.

Technical Committee on Explosives

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W. S. Chang, Bureau of Explosives Lab, NJ

John A. Conkling, Chestertown, MD

C. James Dahn, Safety Consulting Engr Inc., IL

Paul W. Dickinson, Defense Logistics Agency, CO

Thomas P. Dowling, Inst. of Makers of Explosives, DC
Rep. Inst. of Makers of Explosives

Frank H. Fenton, III, The Township of Northampton, PA

Richard L. Fischer, Mine Safety & Health Admin, CO

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John G. Robert, Industrial Risk Insurers, CT
Rep. Industrial Risk Insurers

Robert A. VanDuzer, SAAMI, PA
Rep. Sporting Arms & Ammunition Mfrs. Inst., Inc.

Alternates

Michael S. Katich, Defense Logistics Agency, CO
(Alt. to P. W. Dickinson)

Roger N. Prescott, Austin Powder Co., OH
(Alt. to T. P. Dowling)

Lon D. Santis, U.S. Bureau of Mines, PA
(Alt. to J. E. Hay)

David S. Shatzer, U.S. Bureau of Alcohol, Tobacco & Firearms, DC
(Alt. to L. J. McCune)

Nonvoting

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Charles Schultz, U.S. Dept. of Transportation, DC

Terence P. Smith, U.S. Dept. of Labor, DC
(Alt. to G. E. Gardner)

David G. Trebisacci, NFPA Staff Liaison

This list represents the membership at the time the Committee was balloted on the text of this edition. Since that time, changes in the membership may have occurred.

NOTE: Membership on a Committee shall not in and of itself constitute an endorsement of the Association or any document developed by the Committee on which the member serves.

Committee Scope: This Committee shall have primary responsibility for documents safeguarding against the fire and life hazards associated with explosives and related materials during their manufacture, storage, transportation and use. The sale and use of fireworks and model rockets are the responsibility of the Technical Committee on Pyrotechnics.

NFPA 498
Standard for
Safe Havens and Interchange Lots for
Vehicles Transporting Explosives

1996 Edition

NOTICE: An asterisk (*) following the number or letter designating a paragraph indicates explanatory material on that paragraph in Appendix A.

Information on referenced publications can be found in Chapter 4.

Foreword

Safe havens and interchange lots provide parking and interchange facilities for vehicles transporting explosives. Some explosives interchange lots also provide temporary holding facilities for less-than-truckload quantities of explosives. This standard is designed to prevent the occurrence or spread of fire in facilities where an explosion can present a distinct threat to the surrounding areas.

Explosives motor vehicle facilities are part of the over-the-road transportation of explosives. These facilities not only provide the services noted above, but can also provide vehicle maintenance and driver rest areas.

Motor vehicles using these facilities operate under the regulations of the U.S. Department of Transportation (Title 49 CFR). These vehicles are engaged in transporting explosives and ammunition on government bills of lading, or are often carriers of commercial explosives.

Properly operated explosives motor vehicle facilities provide a safe and controlled environment for parking vehicles carrying explosives. The overall result is improved highway safety.

Chapter 1 General

1-1 Scope.

1-1.1

This standard shall apply to safe havens that are used for the parking of vehicles transporting explosives and to explosives interchange lots that are safe areas where less-than-truckloads of explosives shall be permitted to be held for transfer from one vehicle to another for continuance in transportation.

All vehicles covered by this standard shall be required to be engaged in the transportation of explosives and shall carry shipping papers to show that the explosives being transported are properly described, classified, identified, packaged, and labeled in accordance with regulations of the U.S. Department of Transportation. Additionally, all vehicles shall be required to be marked and placarded in accordance with regulations of the U.S. Department of Transportation.

1-1.2

This standard shall apply to the design and operating features of explosives motor vehicle facilities related to the prevention of fire, theft, and explosion.

1-1.3*

This standard shall not apply to motor freight terminals for vehicles handling general freight.

1-1.4

The requirements of NFPA 513, *Standard for Motor Freight Terminals,* shall apply to explosives motor vehicle facilities where they are applicable and are not covered by this standard.

1-2 Purpose.

This standard shall provide reasonable requirements for the prevention of fires, theft, and explosion within explosives motor vehicle facilities.

1-3 Definitions.

For the purpose of this standard the following terms shall have the meanings given below:

Approved.* Acceptable to the authority having jurisdiction.

Authority Having Jurisdiction.* The organization, office, or individual responsible for approving equipment, an installation, or a procedure.

Explosives Interchange Lot. A specially designated safe area of a motor vehicle terminal where less-than-truckload lots of explosives can be held for transfer from one vehicle to another for continuance in transportation.

Explosives Motor Vehicle Facility. A designated area where motor vehicles transporting explosives can be parked, pending further movement in transportation. Such a facility can be a safe haven or interchange lot and can include maintenance shops, driver rest services, or any combination of these conveniences.

Labeled. Equipment or materials to which has been attached a label, symbol, or other identifying mark of an organization that is acceptable to the authority having jurisdiction and concerned with product evaluation that maintains periodic inspection of production of labeled equipment or materials and by whose labeling the manufacturer indicates compliance with appropriate standards or performance in a specified manner.

Listed.* Equipment, materials, or services included in a list published by an organization acceptable to the authority having jurisdiction and concerned with evaluation of products or services that maintains periodic inspection of production of listed equipment or materials or periodic evaluation of services and whose listing states either that the equipment, material, or service meets identified standards or has been tested and found suitable for a specified purpose.

Motor Vehicle. Any self-propelled vehicle, truck, tractor, semi-trailer, or truck-trailer combination used for the transportation of freight over public highways.

Safe Haven.* A secured area specifically designated and approved in writing by local, state, or federal governmental authorities for the parking of vehicles containing Division 1.1, Division 1.2, or Division 1.3 materials (explosives).

Shall. Indicates a mandatory requirement.

Shipping Papers. A shipping order, bill of lading, manifest, or other shipping document serving a similar purpose and containing the information required by regulations of the U.S. Department of Transportation as specified in Title 49 CFR, Parts 172.202, 172.203, and 172.204.

Should. Indicates a recommendation or that which is advised but not required.

Chapter 2 Safe Havens

2-1 General.

2-1.1

All safe havens shall be located in a secured area that complies with the provisions of this chapter.

2-1.2

Safe havens shall not be located within 300 ft (91.5 m) of a bridge, tunnel, dwelling, building, or place where people work, congregate, or assemble.

Exception: Facilities and personnel related to the operation of the safe haven.

2-1.3

Weeds, underbrush, vegetation, or other combustible materials shall be cleared for a distance of 25 ft (7.6 m) from the safe haven.

2-1.4*

The safe haven shall be protected from unauthorized persons or trespassers by use of warning signs, gates, and patrols specified in 2-4.1.

When vehicles carrying Division 1.1, Division 1.2, or Division 1.3 materials (explosives) are parked in a safe haven, the entrance to the safe haven shall be marked with this warning sign:

DANGER NO SMOKING
NEVER FIGHT EXPLOSIVE FIRES
VEHICLES ON THIS SITE CONTAIN EXPLOSIVES
CALL ________________

The sign shall be weatherproof with reflective printing, and the letters shall be at least 2 in. high.

2-1.5

Watch personnel assigned to patrol the safe haven shall be made familiar with the information in NFPA 601, *Standard for Security Services in Fire Loss Prevention.*

2-1.5.1 All watch personnel at the safe haven shall be made aware of the classification of explosives (Division 1.1, Division 1.2, or Division 1.3) in each vehicle and its inherent dangers, and shall have been instructed in the measures and procedures to be followed in order to protect the public from these dangers.

2-1.5.2 A motor vehicle in good operating condition and capable of moving the explosives-laden trailers in the safe haven shall be kept at the safe haven at all times. The watch or patrol personnel shall be familiar with the vehicle, trained in its use, and supplied with the necessary means and authority to use the motor vehicle to move any of the explosives-loaded vehicles in the safe haven where required. The motor vehicle shall not be parked within 25 ft (7.6 m) of any vehicle containing explosives.

2-1.6

Fire protection equipment capable of handling incipient fires shall be provided at each safe haven. Two or more portable fire extinguishers with a total fire extinguisher rating of at least 4-A:70-B:C shall be placed at accessible locations in the safe haven. Where a dependable water supply source is readily accessible, water hoses shall be permitted to be used in addition to the required portable extinguishers.

2-2 Vehicle Parking.

2-2.1

Before any vehicle is admitted to a safe haven a thorough inspection shall be made of the unit. As a minimum, the vehicle shall be checked for hot tires, hot wheel bearings, hot brakes, any accumulation of oil or grease, any defects in the electrical system, or any apparent physical damage to the vehicle that could cause or contribute to a fire. Any defects shall be corrected before the vehicle is placed in the safe haven.

2-2.2

After a loaded trailer is properly positioned in the safe haven, the tractors shall be disconnected immediately and removed from the safe haven.

2-2.3

Spacing of not less than 5 ft (1.5 m) shall be maintained between parked trailers, side by side, or back to back. Parking shall be maintained so as not to require the moving of one vehicle in order to move another vehicle.

2-2.4

Trailers in the safe haven shall be maintained in the same condition as is required for highway transportation, including placarding.

2-2.5

Where a self-propelled vehicle loaded with explosives is parked in a safe haven it shall be parked at least 25 ft (7.6 m) from any other vehicles containing explosives, and shall be in operable condition, properly placarded, and in a position and condition where it can be moved easily in case of necessity or emergency.

2-2.6

No explosives shall be transferred from one vehicle to another in a safe haven except in case of necessity or emergency.

2-2.7*

No vehicle transporting other hazardous materials shall be parked in a safe haven unless the materials being transported are compatible with explosives.

2-3 Control of Ignition Sources.

2-3.1

Except for minor repairs, no other repair work shall be performed on any vehicle parked in a safe haven. Any repair work involving cutting or welding, operation of the vehicle engine, or the electrical wiring shall be performed only after the explosives have been unloaded from the vehicle, and the vehicle to be repaired has been removed from the safe haven.

2-3.2

Smoking, matches, open flames, spark-producing devices, and firearms shall be prohibited inside or within 50 ft (15.3 m) of the safe haven.

Exception: Law enforcement and security personnel shall be permitted to carry firearms where specifically authorized by the authority having jurisdiction.

2-3.3

Electric service lines required to be in close proximity to a safe haven shall be no closer than the length of the lines between the poles or towers supporting the lines, unless an effective means is provided to ensure that energized lines, on breaking, cannot come into contact with vehicles parked in the safe haven.

2-4 Security Against Trespassers.

2-4.1

When any vehicle transporting explosives is parked in a safe haven, at least one trained person, 21 years of age or older, shall be assigned to patrol the safe haven on a dedicated basis.

Exception: Safe havens located on explosives manufacturing facilities or at motor vehicle terminals shall employ other means of acceptable security such as existing plant or terminal protection systems or electronic surveillance devices.

2-5 Employee Training.

2-5.1

The operator of the safe haven shall maintain an active safety training program in emergency response procedures for all employees working at the safe haven. Written emergency instructions shall be posted and readily accessible to all employees. Employees involved in the loading, shipping, or transportation of explosives shall receive hazardous material training as required by the U.S. Department of Transportation (Title 49 CFR, Subpart H, Sections 172.700 through 172.704) and shall be familiar with the U.S. Department of Transportation *Emergency Response Guide* (ERG) (RSPA-5800.6).

2-6 Notification of Authority Having Jurisdiction.

2-6.1

The operator of the safe haven shall notify, in writing (with signed receipt), local fire department, law enforcement, and emergency response agencies of the establishment and approval of a safe haven, and advise of the type and maximum quantity of Division 1.1, Division 1.2, and Division 1.3 materials authorized for the safe haven. Copies of the safe haven approval and emergency response notifications shall be maintained by the safe haven operator.

Chapter 3 Explosives Interchange Lots

3-1

General.

3-1.1*

A temporary holding facility conforming to the construction requirements for Type 1 or Type 2 magazines as described in NFPA 495, *Explosive Materials Code*, shall be provided in the interchange lot. If detonators or other initiators are to be temporarily held at the same time as other explosives, then two temporary holding facilities shall be required; one for detonators (initiators) and the second for the other explosives.

3-1.2

The facilities specified in 3-1.1 shall be located a minimum of 50 ft (15.3 m) from structures on the adjoining property or from any facility that could create a fire hazard.

3-1.3

Where an area at the loading dock is designated for the temporary holding of explosives in a trailer (as provided in Section 3-2), it shall not be located within 50 ft (15.3 m) of a fire hazard such as an area where smoking is permitted, where hot work is being done, or where combustible or flammable materials are present.

3-2

Operations.

3-2.1

Explosives brought into the interchange lot to await shipment shall be immediately placed in the facility specified in 3-1.1 until such time as the explosives are loaded on a departing over-the-road motor vehicle.

3-2.2

Explosives delivered to the interchange lot by a connecting carrier shall be retained in the trailer at a designated section of the loading dock, or the trailer shall be parked in an isolated area of the interchange lot, or the explosives shall be placed in the holding facility.

3-2.3

The explosives transport vehicles, including trailers, in the interchange lot shall be maintained in the same condition as is required for highway transportation, including placarding.

3-2.4

Explosives shall not be retained on the lot, either in a trailer or holding facility, for a period longer than necessary, but in no case for more than 100 hours.

3-2.5

Smoking, matches, open flames, spark-producing devices, and firearms shall be prohibited inside of and within 50 ft (15.3 m) of the temporary holding facility or trailer containing explosives.

Exception: Law enforcement and security personnel shall be permitted to carry firearms where specifically authorized by the authority having jurisdiction.

3-2.6

Temporary facilities as specified in 3-1.1 shall be appropriately marked so that the interchange lot employees are aware of the location.

3-2.7

Portable fire extinguishers, having a capacity of 4-A:70-B:C, shall be placed at each temporary holding facility and shall be readily available for immediate use.

3-2.8

The operator of the explosives motor vehicle interchange lot shall maintain an active training program in emergency procedures for all employees stationed at the interchange lot. Written emergency instructions shall be posted and readily accessible to all employees. Employees involved in the loading, shipping, or transportation of explosives shall receive hazardous material training as required by the U.S. Department of Transportation (49 CFR, Subpart H, Sections 172.700 through 172.704) and shall be familiar with the U.S. Department of Transportation *Emergency Response Guide* (ERG) (RSPA-5800.6). Any driver who transports a vehicle loaded with explosives over public highways shall possess a valid commercial driver's license (CDL) with a hazardous material endorsement (H).

Chapter 4 Referenced Publications

4-1

The following documents or portions thereof are referenced within this standard and shall be considered part of the requirements of this document. The edition indicated for each reference is the current edition as of the date of the NFPA issuance of this document.

4-1.1 NFPA Publications.

National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.

NFPA 495, *Explosive Materials Code*, 1996 edition.

NFPA 513, *Standard for Motor Freight Terminals*, 1994 edition.

NFPA 601, *Standard for Security Services in Fire Loss Prevention*, 1996 edition.

4-1.2 Federal Government Publications.

Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402.

ERG RSPA-5800.6, *Emergency Response Guide*.

Title 49 CFR, Parts 325 through 399, *Federal Motor Carrier Safety Regulations*.

Title 49 CFR, Parts 100 through 199, *Hazardous Materials Regulations*.

Appendix A Explanatory Material

This Appendix is not a part of the requirements of this NFPA document but is included for informational purposes only.

A-1-1.3 See NFPA 513, Standard for Motor Freight Terminals.

A-1-3 Approved. The National Fire Protection Association does not approve, inspect, or certify any installations, procedures, equipment, or materials; nor does it approve or evaluate testing laboratories. In determining the acceptability of installations, procedures, equipment, or materials, the authority having jurisdiction may base acceptance on compliance with NFPA or other appropriate standards. In the absence of such standards, said authority may require evidence of proper installation, procedure, or use. The authority having jurisdiction may also refer to the listings or labeling practices of an organization concerned with product evaluations that is in a position to determine compliance with appropriate standards for the current production of listed items.

A-1-3 Authority Having Jurisdiction. The phrase "authority having jurisdiction" is used in NFPA documents in a broad manner, since jurisdictions and approval agencies vary, as do their responsibilities. Where public safety is primary, the authority having jurisdiction may be a federal, state, local, or other regional department or individual such as a fire chief; fire marshal; chief of a fire prevention bureau, labor department, or health department; building official; electrical inspector; or others having statutory authority. For insurance purposes, an insurance inspection department, rating bureau, or other insurance company representative may be the authority having jurisdiction. In many circumstances, the property owner or his or her designated agent assumes the role of the authority having jurisdiction; at government installations, the commanding officer or departmental official may be the authority having jurisdiction.

A-1-3 Listed. The means for identifying listed equipment may vary for each organization concerned with product evaluation, some of which do not recognize equipment as listed unless it is also labeled. The authority having jurisdiction should utilize the system employed by the listing organization to identify a listed product.

A-1-3 Safe Haven. See Title 49 CFR, Part 397.5.

A-2-1.4 The sign does not need to be displayed when there are no explosives-laden vehicles in the safe haven.

A-2-2.7 In case of an emergency where vehicles loaded with other hazardous materials are brought to a safe haven, such vehicles should be parked at a location on the lot well separated from the explosives-laden vehicles.

A-3-1.1 Temporary holding facilities should be separated as far as practicable to reduce the concentration of explosives in any single area of the terminal.

Appendix B Referenced Publications

B-1 The following documents or portions thereof are referenced within this standard for informational purposes only and thus are not considered part of the requirements of this document. The edition indicated for each reference is the current edition as of the date of the NFPA issuance of this document.

B-1.1 NFPA Publication. National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.

NFPA 513, Standard for Motor Freight Terminals, 1994 edition.

B-1.2 Other Publications.

B-1.2.1 U.S. Government Publication. U.S. Government Printing Office, Washington, DC 20402.

Title 49 CFR, Part 397.5.

NFPA 501A

1992 Edition

Standard for Fire Safety Criteria for Manufactured Home

Installations, Sites, and Communities

1992 Edition

This edition of NFPA 501A, *Standard for Fire Safety Criteria for Manufactured Home Installations, Sites, and Communities,* was prepared by the Technical Committee on Manufactured Homes and acted on by the National Fire Protection Association, Inc. at its Annual Meeting held May 18-21, 1992 in New Orleans, LA. It was issued by the Standards Council on July 17, 1992, with an effective date of August 14, 1992, and supersedes all previous editions.

The 1992 edition of this document has been approved by the American National Standards Institute.

Origin and Development of NFPA 501A

NFPA activity in this general area commenced in 1937 when NFPA organized its first

Committee on Trailers and Trailer Courts. The first standard covering trailer coach camps appeared in 1939, with revisions in 1940, 1952, 1960, and 1964. A completely new edition was adopted in 1971, and this text was revised in 1972, 1973, 1974, 1975, 1977, and 1982.

The American National Standards Institute (ANSI) approved the 1972 NFPA edition on May 8, 1973; the 1973 NFPA edition on December 28, 1973; the 1974 NFPA edition on January 30, 1975; the 1975 NFPA edition on February 27, 1976; and the 1977 NFPA edition on October 18, 1977.

The 1982 edition of *Standard for Firesafety Criteria for Mobile Home Installations, Sites, and Communities* superseded the 1977 edition and was adopted by NFPA at its Annual Meeting held in San Francisco on May 19, 1982.

The 1982 edition was produced by the newly formed Committee for Firesafety for Mobile Homes (June 10, 1979) charged with the responsibility of developing documents for fire safety criteria for single-family mobile homes including the installation, sites, and communities, and the maintenance of and improvements for existing mobile homes. Therefore, that edition excluded all sections of previous editions not considered within the Committee scope. Notably excluded were stabilizing and anchoring systems, requirements for piers and footings, and plumbing, including sewage disposal systems. Requirements for park electrical systems were addressed by reference to the *National Electrical Code*.®

Modifications were also made in sections dealing with fuel supply, air conditioning, and life and fire safety.

Major revisions to the standard were made in the 1987 edition in an attempt to better coordinate the NFPA chapters in a joint publication with NCSBCS, ANSI A225.1/ NFPA 501A. Major changes included substituting “manufactured home” for “mobile home” throughout, deleting Chapter 3, “Air Conditioning,” expanding Chapter 2, “Fuel Supply,” and combining three appendixes into two.

The standard was reconfirmed in 1992 with a plan to expand the scope of NFPA 501A to cover fire safety requirements for the design, construction, installation, alteration/rehabilitation, maintenance, use, and occupancy of manufactured homes, manufactured home sites, manufactured home communities including accessory buildings, and structures. This will be a major revision of the scope and the entire standard, and the Committee has targeted a complete revision of 501A for 1994.

NOTICE: NFPA has previously published A225.1/501A as jointly developed by NFPA and NCSBCS. This edition of NFPA 501A includes only the fire safety portion of this document. The non-fire-safety portion is being published separately as A225.1 by NCSBCS.

Technical Committee on Manufactured Homes

Travis Pitts, *Chairman*
California Dept. of Housing & Community Development, CA

Jesse J. Beitel, Southwest Research Institute, MD

NFPA 501A

Standard for Fire Safety Criteria for Manufactured Home Installations, Sites, and Communities

1992 Edition

NOTICE: An asterisk (*) following the number or letter designating a paragraph indicates explanatory material on that paragraph in Appendix A.

Information on referenced publications can be found in Chapter 5 and Appendix D.

Chapter 1 Scope, Intent of Standard, and Definitions

1-1 Scope.

This standard covers fire safety requirements for the installation of manufactured homes and manufactured home sites, including accessory buildings, structures, and communities.

The provisions of this standard shall not apply to recreational vehicles as defined in NFPA 501C, *Standard on Recreational Vehicles,* or to park trailers as defined in the ANSI A119.5, *Standards for Park Trailers*.

1-2 Definitions.

Approved.* Acceptable to the "authority having jurisdiction."

Authority Having Jurisdiction.* The "authority having jurisdiction" is the organization, office or individual responsible for "approving" equipment, an installation or a procedure.

Awning. A shade structure supported by posts or columns, or partially supported by a manufactured home, installed, erected, or used on a manufactured home site.

Cabana. A portable, demountable, or permanent room enclosure or other building erected or constructed for human occupancy.

Carport. An awning or shade structure for a vehicle or vehicles that may be either freestanding or partially supported by a manufactured home.

Community Building. Any nonresidential building used for manufactured home community purposes.

Community Management. The person or entity who owns a development or has charge, care, or control of a community (park, estate, subdivision, etc.).

Community Street. A private way that affords principal means of access to abutting individual sites, homes, and buildings.

Dwelling Unit. One or more habitable rooms designed to be occupied by one family with facilities for living, sleeping, cooking, eating, and sanitation.

Garage. A structure, located on a manufactured home site, designed for the storage of motor vehicles.

Gas Supply Connector, Manufactured Home. A listed connector designed for connecting the manufactured home to the gas supply source.

Habitable Room. A room or enclosed floor space arranged for living, eating, food preparation, or sleeping purposes not including bathrooms, toilet compartments, laundries, pantries, foyers, hallways, and other accessory floor space.

Labeled. Equipment or materials to which has been attached a label, symbol or other identifying mark of an organization acceptable to the “authority having jurisdiction” and concerned with product evaluation, that maintains periodic inspection of production of labeled equipment or materials and by whose labeling the manufacturer indicates compliance with appropriate standards or performance in a specified manner.

Listed.* Equipment or materials included in a list published by an organization acceptable to the “authority having jurisdiction” and concerned with product evaluation, that maintains periodic inspection of production of listed equipment or materials and whose listing states either that the equipment or material meets appropriate standards or has been tested and found suitable for use in a specified manner.

Manufactured Home.* A structure, transportable in one or more sections, that, in the traveling mode, is 8 body feet (2.4 m) or more in width and 40 body feet (12 m) or more in length or, when erected on site, is 320 or more square feet (28.8 m^2), that is built on a permanent chassis and designed to be used as a dwelling with or without a permanent foundation when connected to the required utilities, and that includes the plumbing, heating, air conditioning, and electrical systems contained therein.

Manufactured Home Accessory Building or Structure. A building or structure that is an addition to or supplements the facilities provided in a manufactured home. It is not a self-contained, separate, habitable building or structure. Examples are awnings, cabanas, garages, ramadas, storage structures, carports, fences, windbreaks, or porches.

Manufactured Home Site. A parcel of land for the accommodation of one manufactured home, its accessory building or structures, and accessory equipment for the exclusive use of the occupants.

Porch. An outside walking area having the floor elevated more than 8 in. (203 mm) above grade.

Ramada. Any freestanding roof or shade structure, installed or erected above a manufactured home or any portion thereof.

Shall. Indicates a mandatory requirement.

Should. Indicates a recommendation or that which is advised but not required.

Chapter 2 Fuel Supply

2-1 Fuel Supply.

2-1.1* General.

All fuel gas piping systems serving manufactured homes, accessory buildings, or structures and communities shall be designed and constructed in accordance with any applicable provisions of NFPA 54, *National Fuel Gas Code*, and NFPA 58, *Standard for the Storage and Handling of Liquefied Petroleum Gases*. NFPA 31, *Standard for Installation of Oil-Burning Equipment*, shall apply to oil fuel-burning systems and shall conform to the criteria of the authority having jurisdiction.

2-1.2 Gas Supply Connections.

Gas supply connections at sites, where provided from an underground gas supply piping system, shall be located and arranged to permit attachment to a manufactured home occupying the site in a worklike manner. For the installation of liquefied petroleum gas storage systems, the applicable provisions of NFPA 58, *Standard for the Storage and Handling of Liquefied Petroleum Gases*, shall be followed.

2-1.3 Location of Gas Supply Connection.

The gas supply to the manufactured home shall be located within 4 ft (1.22 m) of the manufactured home stand. (*See also Sections 2-3 and 2-4, 2-3.2 and 2-4.5.*)

Exception: The above requirements do not apply to gas supply connections for manufactured homes located on all-weather wood or concrete or concrete block foundation systems or on foundations constructed in accordance with the local building code or, in the absence of a local code, with a recognized model building code.

2-2 Single and Multiple Manufactured Home Site Fuel Supply Systems.

2-2.1 Gas Piping Installations.

2-2.1.1 Gas Supply Connections — Underground Gas Piping. Gas supply connections at sites, where provided from an underground gas supply piping system, shall be located and arranged to permit attachment in a worklike manner to a manufactured home occupying the site. For the installation of liquefied petroleum gas storage systems, the provisions of NFPA 58, *Standard for the Storage and Handling of Liquefied Petroleum Gases*, shall be followed.

2-2.1.2 Underground gas piping system installations shall comply with any applicable building code and the following:

(a) Gas piping shall not be installed underground beneath that portion of a manufactured home site reserved for the location of a manufactured home, or a manufactured home accessory building or structure, unless installed in an open-ended gastight conduit. The conduit shall conform to the following:

1. The conduit shall be a pipe approved for installation underground beneath buildings and shall be not less than Schedule 40 pipe. The interior diameter of the conduit shall be not less than $^{1}/_{2}$ in. (13 mm) larger than the outside diameter of the gas piping.

2. The conduit shall extend to a point not less than 4 in. (102 mm) beyond the outside wall of the manufactured home, accessory building, or structure, and the outer ends shall not be sealed. Where the conduit terminates within a manufactured home, accessory building, or structure, it shall be readily accessible and the space between the conduit and the gas piping shall be sealed to prevent leakage of gas into the building.

2-2.2 Manufactured Home Site Gas Shutoff Valve.

Each manufactured home site shall have a listed gas shutoff valve installed upstream of the manufactured home site gas outlet, and it shall be located on the outlet riser at a height of not less than 6 in. (152 mm) above grade. Such valve shall not be located under any manufactured home. The outlet shall be equipped with a cap or plug to prevent discharge of gas whenever the manufactured home site outlet is not connected to a home.

Exception: All gas shutoff valves for manufactured homes located on foundations constructed in accordance with the local building code or, in the absence of a local code, with a recognized model building code.

2-2.3 Gas Meters.

2-2.3.1 Support of Meters. Where gas meters are installed, they shall not depend on the gas outlet riser for support, but shall be adequately supported by a post or bracket placed on a firm footing or other means providing equivalent support.

2-2.3.2* Location of Meters. Each meter installed shall be in an accessible location and shall be provided with unions or other fittings so that the motor is easily removable and replaceable in an upright position. Meters shall not be installed in unventilated or inaccessible locations or closer than 3 ft (0.91 m) to sources of ignition.

2-2.4 Meter Shutoff Valve or Cock.

All gas meter installations shall be provided with shutoff valves or cocks located adjacent to and on the inlet side of the meters. In the case of a single meter installation utilizing a liquefied petroleum gas container, the container service valve may be used in lieu of the shutoff valve or cock. All gas meter installations shall be provided with test tees located adjacent to and on the outlet side of the meters.

2-3 Multiple Manufactured Home Site Fuel Distribution and Supply Systems.

(*See also Sections 2-1 and 2-4, 2-3.5, and 2-4.5*.)

2-3.1 Manufactured Home Community Gas Distribution and Supply Systems.

2-3.1.1* Manufactured Home Community Natural-Gas Distribution Systems. All underground metallic fuel piping systems shall comply with the cathodic protection requirements of 49 CFR, Parts 191 and 192.

2-3.1.2 Liquefied Petroleum Gas Supply Systems. Where ten or more customers are served by one liquefied petroleum gas supply system, the installation shall be in accordance with 49 CFR, Part 192, *Transportation of Natural and Other Gas by Pipeline: Minimum Federal Safety Standards*. For other systems and for the storage and handling of liquefied petroleum gas, NFPA 58, *Standard for the Storage and Handling of Liquefied Petroleum Gases,* shall be followed. (*See also 2-3.2*.)

2-3.1.3 Installation of Cathodic Protection Systems. Where required by the federal standard cited in 2-3.1.1, cathodic protection shall be installed for corrosion control of buried or submerged metallic gas piping. [*See also 2-3.1.6(a) and (b)*.]

2-3.1.4 Required Gas Supply. The minimum hourly volume of gas required at each manufactured home site outlet or any section of the manufactured home community gas piping system shall be calculated as shown in Table 2-3.1.4.

Table 2-3.1.4 Demand Factors for Use in Calculating Gas Piping Systems in Manufactured

Home Communities

No. of Manufactured Home Sites	Btu per Hour per Manufactured Home Site
1	125,000
2	117,000
3	104,000
4	96,000
5	92,000
6	87,000
7	83,000
8	81,000
9	79,000
10	77,000
11-20	66,000
21-30	62,000
31-40	58,000
41-60	55,000
Over 60	50,000

NOTE: In extreme climate areas, additional capacities should be considered.

2-3.1.5 Gas Pipe Sizing and Pressure.

(a) The size of each section of a gas piping system shall be determined in accordance with NFPA 54, *National Fuel Gas Code*, or by other standard engineering methods acceptable to the authority having jurisdiction.

(b) Where all connected appliances are operated at their rated capacity, the supply pressure shall be not less than 4 oz per sq in. (7 in. water column) (1743 Pa). The gas supply pressure shall not exceed 8 oz per sq in. (14 in. water column) (3486 Pa).

2-3.1.6 Gas Piping Materials.

(a) *Metal.* Metal gas pipe shall be standard weight wrought iron or steel (galvanized or black), yellow brass containing not more than 75 percent copper, or internally tinned or treated copper of iron pipe size. Galvanizing shall not be considered protection against corrosion.

Seamless copper or steel tubing shall be permitted to be used with gases not corrosive to such material. Steel tubing shall comply with ANSI/ASTM A539, *Standard Specification for Electric-Resistance-Welded Coiled Steel Tubing for Gas and Fuel Oil Lines*, or ANSI/ASTM A254, *Standard Specification for Copper Brazed Steel Tubing*. Copper tubing shall comply with ANSI/ASTM B88, *Specification for Seamless Copper Water Tubing* (Type K or L) or ANSI/ASTM B280, *Specification for Seamless Copper Tubing for Air Conditioning and Refrigeration Field Service*. Copper tubing (unless tin-lined) shall not be used if the gas contains more than an average of 0.3 grains of hydrogen sulfide per 100 standard cubic feet of gas.

(b) *Protection Coatings for Metal Gas Piping.* All buried or submerged metallic gas piping shall be protected from corrosion by approved coatings or wrapping materials. All gas pipe protective coatings shall be approved types, be machine applied, and conform to recognized standards. Field wrapping shall provide equivalent protection and is restricted to those short sections and fittings necessarily stripped for threading or welding. Risers shall be coated or wrapped to a point at least 6 in. (152 mm) above ground.

(c) *Plastic.* Plastic piping shall only be used underground and shall meet the requirements of ASTM D2513, *Thermoplastic Gas Pressure Pipe, Tubing, and Fittings,* or ASTM D2517, *Reinforced Epoxy Resin Gas Pressure Pipe and Fittings*, and shall meet the design pressure and design limitations of 49 CFR, Part 192.123 and shall otherwise conform to the installation requirements thereof.

2-3.1.7 Gas Piping Installations.

(a) *Minimum Burial Below Ground Level and Clearances.* All gas piping installed below ground shall have a minimum earth cover of 18 in. (451 mm) and shall be installed with at least 12 in. (305 mm) of clearance in any direction from any other underground utility system.

(b) *Metallic Gas Piping.*

1. *Plan Approval Required.* All metallic gas piping systems shall be installed in accordance with approved plans and specifications, including provisions for cathodic protection. Each cathodic protection system shall be designed and installed to conform to the provisions of 49 CFR, Part 192.

2. *Where Cathodic Protection Is Designed Only to Protect Underground Gas Piping.* Where the cathodic protection system is designed to protect only the gas piping system, the gas piping system shall be electrically isolated from all other underground metallic systems or installations. Where only the gas piping system is cathodically protected against corrosion, a dielectric fitting shall be used in the manufactured home gas connection to insulate the manufactured home from the underground gas piping system.

3. *Where Cathodic Protection Is Designed to Protect All Underground Metallic Systems.* Where a cathodic protection system is designed to provide all underground metallic systems and installations with protection against corrosion, all such systems and installations shall be electrically bonded together and protected as a whole.

(c) *Plastic Gas Piping.* Plastic gas piping shall only be used underground and shall be installed with an electrically conductive wire for locating the pipe. The plastic pipe-locating wire shall be copper, not smaller in size than No. 18 AWG, with insulation approved for direct burial. Every portion of a plastic gas piping system consisting of metallic pipe shall be cathodically protected against corrosion.

(d) *Gas Piping System Shutoff Valve.* A readily accessible and identifiable shutoff valve controlling the flow of gas to the entire manufactured home community gas piping system shall be installed near the point of connection to the service piping or to the supply connection of a liquefied petroleum gas container.

2-3.2 Liquefied Petroleum Gas Equipment.

LP-Gas equipment shall be installed in accordance with the applicable provisions of NFPA 58, *Standard for the Storage and Handling of Liquefied Petroleum Gases*.

The referenced standard, NFPA 58, includes provisions on: location of containers; installation of containers; installation of container appurtenances; regulator installations; piping system service limitations; installation of pipe, tubing, pipe and tubing fittings, valves, and hose; and hydrostatic relief valve installation.

2-3.3 Oil Supply.

The following three methods of supplying oil to an individual manufactured home site shall be permitted:

(a) Supply from an outside underground tank. (*See 2-4.6*.)

(b) Supply from a centralized oil distribution system designed and installed in accordance with accepted engineering practices and in compliance with NFPA 31, *Standard for the Installation of Oil-Burning Equipment*.

(c) Supply from an outside aboveground tank. (*See 2-4.6*.)

2-3.4 Minimum Oil Supply Tank Size.

Oil supply tanks shall have a minimum capacity equal to 20 percent of the average annual oil consumption. [Sixty-gal (230-L) ICC-5 shipping containers or drums are not recommended, except for areas with less than 1,800 degree-days.]

2-3.5 Oil Supply Connections — General.

Oil supply connections at manufactured home stands, where provided from a centralized oil distribution system, shall be located and arranged to permit attachment in a worklike manner to a manufactured home utilizing the stand. The installation of such facilities shall meet the provisions of NFPA 31, *Standard for the Installation of Oil-Burning Equipment*, and particularly Section 3-8 thereof.

2-4 Fuel Supply Systems Installation.

2-4.1* Flexible Gas Connector.

Each gas supply connector shall be listed for outside manufactured home use, be not more than 6 ft (1.83 m) in length, and have a capacity rating adequate to supply the connected load.

Exception: All gas supply connections for manufactured homes located on an all-weather wood, concrete, or concrete block foundation systems or on a foundation constructed in accordance with the local building code or, in the absence of a local code, with a recognized model building code.

2-4.2 Use of Approved Pipe and Fittings of Extension.

Where it is necessary to extend the manufactured home inlet to permit connection of the 6-ft (1.83-m) listed connector to the site gas outlet, the extension shall be of approved materials of the same size as the manufactured home inlet and be adequately supported at no more than 4-ft (1.22-m) intervals to the manufactured home.

2-4.3* Mechanical Protection.

Where subject to physical damage, all gas outlet risers, regulators, meters, valves, or other exposed equipment shall be protected against accidental damage.

2-4.4 Special Rules on Atmospherically Controlled Regulators.

Atmospherically controlled regulators shall be installed in such a manner that moisture cannot enter the regulator vent and accumulate above the diaphragm. Where the regulator vent may be obstructed due to snow and icing conditions, shields, hoods, or other suitable devices shall be provided to guard against closing of the vent opening.

2-4.5 Fuel Gas Piping Test.

The manufactured home fuel gas piping system shall be tested with air only before it is connected to the gas supply. The manufactured home gas piping system shall be subjected to a pressure test with all appliance shutoff valves in their closed position.

(a) The test shall consist of air pressure at not less than 10 in. nor more than 14 in. water column (6 to 8 oz per sq in.) (2490 to 3486 Pa). The system shall be isolated from the air pressure source and shall maintain this pressure for not less than 10 minutes without perceptible leakage. Upon satisfactory completion of the test, the appliance valves shall be opened and the gas appliance connectors tested with soapy water or bubble solution while under the pressure remaining in the piping system. Solutions used for testing for leakage shall not contain corrosive chemicals. Pressure shall be measured with either a manometer, slope gage, or gage calibrated in either water in. or psi with increments of either $^{1}/_{10}$ in. or $^{1}/_{10}$ psi, as applicable. Upon satisfactory completion of the test, the manufactured home gas supply connector shall be installed and the connections tested with soapy water or bubble solution.

WARNING: Do Not Overpressurize the Fuel Gas Piping System! Pressurization beyond the maximums specified may result in damage to valves, regulators, appliances, etc.

(b) Gas appliance vents shall be visually inspected to ensure that they have not been dislodged in transit and are securely connected to the appliance.

2-4.6 Oil Tanks.

Not more than one 660 gal (2500 L) tank or two tanks of aggregate capacity of 660 gal (2500 L) or less shall be connected to one oil-burning appliance. Two supply tanks, where used, shall be cross-connected and provided with a single fill and single vent as described in Appendix A of NFPA 31, *Standard for the Installation of Oil-Burning Equipment*; but when so connected, they shall be on a common slab and rigidly secured, one to the other. Tanks having a capacity of 660 gal (2500 L) or less shall be securely supported by rigid noncombustible supports to prevent settling, sliding, or lifting.

2-4.6.1* Oil supply tanks shall be installed in accordance with the applicable provisions of

NFPA 31, *Standard for the Installation of Oil-Burning Equipment*. Chapter 2 of the referenced standard includes provisions on the design and construction of tanks, installation of underground tanks, outside aboveground tanks not larger than 660 gal (2500 L), and location with respect to adjacent buildings and adjoining property lines.

2-4.6.2 A tank not larger than 60 gal (230 L) capacity shall be permitted to be a DOT-5 shipping container (drum), and so marked, or a tank meeting the provisions of UL 80, *Steel Inside Tank for Oil Burner Fuel*. Tanks other than DOT-5 shipping containers having a capacity of not more than 660 gal (2500 L) shall meet the provisions of UL 80. Pressure tanks shall be built in accordance with Section VIII of the ASME *Boiler and Pressure Vessel Code*, Code for Unfired Pressure Vessels.

2-4.6.3 Tanks as described in 2-4.6 and 2-4.6.2 may be located adjacent to buildings, but shall be located not less than 10 ft (3.05 m) from a property line that may be built upon.

2-4.6.4 Tanks not larger than 660 gal (2500 L) capacity shall be equipped with an open vent not smaller than $1^1/_2$ in. (38 mm) iron pipe size; tanks with a 500 gal (1900 L) or less capacity shall have a vent of $1^1/_4$ in. (32 mm) iron pipe size.

2-4.6.5 Tanks shall be provided with a means to determine the liquid level. [*See Section 3-6 of NFPA 31, Standard for the Installation of Oil-Burning Equipment (ANSI).*]

2-4.6.6 The fill opening shall be of such size and so located to permit ready filling in a manner that will avoid spillage.

2-5 Manufactured Home Accessory Building Fuel Supply Systems.

Fuel gas supply systems installed in a manufactured home accessory building or structure shall comply with the applicable provisions of NFPA 54, *National Fuel Gas Code*, and NFPA 58, *Standard for the Storage and Handling of Liquefied Petroleum Gases*. Fuel oil supply systems shall comply with the applicable provisions of NFPA 31, *Standard for the Installation of Oil-Burning Equipment*.

2-6 Community Building's Fuel Supply Systems.

2-6.1 Fuel Gas Piping and Equipment Installations.

Fuel gas piping and equipment installed within a permanent building in a manufactured home community shall comply with nationally recognized appliance and fuel gas piping codes and standards adopted by the authority having jurisdiction. Where the state or other political subdivision does not assume jurisdiction, such fuel gas piping and equipment installations shall be designed and installed in accordance with the appropriate provisions of NFPA 54, *National Fuel Gas Code*, or NFPA 58, *Standard for the Storage and Handling of Liquefied Petroleum Gases*.

2-6.2 Manufactured Home Community Oil Supply Systems.

Oil-burning equipment and installations within a manufactured home community shall be designed and constructed in accordance with the applicable codes adopted by the authority having jurisdiction. Where the state or other political subdivision does not assume jurisdiction, such installations shall be designed and constructed in accordance with the applicable provisions of the standard referenced in 2-3.5.

2-6.3 Oil-Burning Equipment and Installation.

Oil-burning equipment and installation within a building constructed in accordance with the local building code or a nationally recognized building code in a manufactured home community shall comply with nationally recognized codes and standards adopted by the authority having jurisdiction. Where the state or other political subdivision does not assume jurisdiction, such oil-burning equipment and installation shall be designed and installed in accordance with the appropriate provisions of NFPA 31, *Standard for the Installation of Oil-Burning Equipment*.

Chapter 3 Electrical

3-1 Site and Community Electrical Equipment and Installations.

Sites and communities provided with electrical service shall have all electrical equipment and installations designed, constructed, and maintained in accordance with the applicable provisions of NFPA 70, *National Electrical Code*.®

Chapter 4 Life Safety and Fire Safety

4-1 General.

Responsibility for life safety and fire safety within manufactured home communities is that of the owners and operators of the community.

4-1.1

Arrangement of manufactured homes and accessory buildings or structures on the site shall not restrict reasonable access to the site by emergency personnel. Each community operator shall maintain a community site plan for review by agencies responsible for emergency services including, but not limited to, street names, site separation lines, site numbers, water supplies for fire protection personnel, fire alarms, and utility disconnects.

4-1.2

Each street name shall be clearly marked by signs, and each site marked for identification in a uniform manner clearly visible from the street serving the site.

4-2 Manufactured Home Site Fire Safety Requirements.

4-2.1 Fire Safety Separation Requirements.

4-2.1.1 Any portion of a manufactured home, excluding the tongue, shall not be located closer than 10 ft (3 m) side to side, 8 ft (2.4 m) end to side, or 6 ft (1.8 m) end to end horizontally from any other manufactured home or community building unless the exposed composite walls and roof of either structure are without openings and constructed of materials that will provide a one-hour fire rating or the structures are separated by a one-hour fire-rated barrier. (*See 4-4.1.*)

4-2.1.2 Vertical Positioning of Manufactured Homes. Manufactured homes shall not be positioned vertically (stacked with one over the other) in whole or in part unless the structure is designed and approved for such installation and permitted by the authority having jurisdiction.

4-2.2* Marking of Underground Utility Lines.

The location of electrical cables, gas piping, water piping, and sewer lines buried underground along the periphery or within 4 ft (1.2 m) of the perimeter of the site's largest planned manufactured home shall be indicated by an aboveground sign(s) or underground marker tapes identifying the proximity of the lines. A plot plan showing the "as built" location of underground utility lines shall be available for installations in multiple-site facilities.

4-2.3 Manufactured Home Installations.

4-2.3.1 Installation Instructions. Installations of all manufactured homes, including the support system and connections of structural, electrical, mechanical, and plumbing systems to the site utilities or between sections in the case of multiple-section homes, shall be performed in accordance with printed installation instructions provided by the manufacturer of the home.

For installations where printed instructions by the manufacturer are not available, the installation shall be performed in a manner satisfying the intent of this standard, as determined by the authority having jurisdiction.

The design of support systems shall consider the climatic and geological conditions present at the manufactured home site.

4-2.3.2 Approved Materials Required. All manufactured home utility services shall be connected to the supply sources only with approved materials.

4-2.4 Egress.

Any manufactured home, accessory building, structure, or community building shall be located and maintained in such a manner that any required egress window or door is not blocked.

4-3 Manufactured Home Community Buildings.

4-3.1 Construction.

Every community building shall be designed and constructed in accordance with the applicable provisions of local building codes.

4-3.1.1 Materials, Fixtures, Devices, Fittings. Materials, fixtures, devices, and fittings, and their installation shall conform to nationally recognized standards.

4-3.2 Incinerators and Rubbish Burning.

4-3.2.1 Burning of rubbish within a community shall not be permitted unless specifically permitted by the authority having jurisdiction.

4-3.2.2 Incinerators, where permitted by the authority having jurisdiction, shall be constructed in accordance with NFPA 82, *Standard on Incinerators, Waste, and Linen Handling Systems and Equipment*.

4-3.2.3 Incinerators, where permitted by the authority having jurisdiction, shall meet the applicable standards of the Environmental Protection Agency having jurisdiction.

4-3.3 Outdoor Hazards.

All areas of the community and individual sites shall be maintained free of dry brush, leaves, weeds, and other debris that could contribute to the spread of fire within the site or community.

4-3.4 Fire Detection and Alarm Systems.

4-3.4.1* Detection Systems in Community Buildings. Fire detection and alarm systems installed in community buildings shall be installed in accordance with NFPA 72, *Standard for the Installation, Maintenance, and Use of Protective Signaling Systems*.

4-3.4.2 Public Fire Alarm Services. Street fire alarm services for the community, where provided, shall be in accordance with NFPA 1221, *Standard for the Installation, Maintenance, and Use of Public Fire Service Communication Systems*. Where such services are not provided, alarm procedures shall be posted as required by the local fire service.

4-3.5 Water Supplies for Fire Protection — Minimum Requirements.

Water supplies for fire department operations shall be as required by the authority having jurisdiction. Where there are no such requirements, water supplies shall be at least adequate to permit the effective operation of two $1^1/_2$-in. (38 mm) hose streams on any fire in a building. The supply may be derived from hydrants connected to an underground water supply system, a reservoir or water supply with a source of not less than 3,000 gal (11,360 L) (accessible fire department drafting operations), or fire department apparatus equipped with a water tank(s) with a capacity of 750 gal (2840 L) and a pump capacity of 250 gpm (16 L/s), constructed in accordance with NFPA 1901, *Standard for Pumper Fire Apparatus*.

Hydrants, where provided, shall be located along the community streets or public ways readily accessible for fire department use and located within 500 ft (152.4 m) of all homes and buildings. Hydrant-hose coupling threads shall be national standard threads (*see NFPA 1963, Standard for Screw Threads and Gaskets for Fire Hose Connections*) or shall conform to those used by the local fire department if different from those specified in the referenced standard.

4-3.6 Manufactured Home and Community Fire Safety Requirements.

4-3.6.1 Use and Maintenance of Space Under Manufactured Homes, Accessory Buildings, or Structures. The space under manufactured homes and accessory buildings and structures shall not be used for the storage of combustible materials or for the storage or placement therein of flammable liquids, gases, or liquid- or gas fuel-powered equipment. (*See Appendix B.*)

4-3.6.2 Emergency Information. The requirements of this section shall be printed and posted in conspicuous places in the community and shall contain the following information.

(a) List the following phone numbers:

1. Fire department.
2. Police department or sheriff's office.
3. Community office.
4. The person responsible for operation and maintenance.

(b) List the following locations:

1. Nearest fire alarm box, where available.
2. Nearest public telephone.

3. Address of community.

4-3.6.3* Portable Fire Extinguishers. Portable fire extinguishers, where required or installed, shall be of the type and size required by NFPA 10, *Standard for Portable Fire Extinguishers*.

4-3.6.4 Life Safety from Fire. The provisions of NFPA *101*,® *Life Safety Code*,® regarding construction, protection, and occupancy features of community buildings to minimize danger to life from fire, smoke, or panic shall be followed, as applicable, with special attention given the number, size, and arrangement of exit facilities in community buildings used as places of public assembly.

4-3.6.5 Portable Fire Fighting Equipment. Community buildings shall be provided with listed portable fire extinguishers in accordance with the applicable provisions of NFPA 10, *Standard for Portable Fire Extinguishers*.

4-4 Accessory Building or Structure Fire Safety Requirements.

4-4.1 Setback Requirements.

Accessory buildings or structures shall be permitted to be located immediately adjacent to a site line where constructed entirely of materials that do not support combustion and provided that such buildings or structures are not less than 3 ft (0.9 m) from an accessory building or structure on an adjacent site. An accessory building or structure constructed of combustible materials shall be located not closer than 5 ft (1.5 m) from the site line of an adjoining site.

4-4.2 Exits.

Every habitable room in an accessory building or structure shall have access to at least one exterior opening suitable for exiting directly to the outside without passing through the manufactured home. Where a building or structure encloses two doors of the manufactured home or an emergency exit window, an additional exterior door shall be installed. This exterior door shall be not less than 28 in. (0.7 m) in width and 6 ft 2 in. (1.9 m) in height.

Chapter 5 Referenced Publications

5-1

The following documents or portions thereof are referenced within this standard and shall be considered part of the requirements of this document. The edition indicated for each reference is the current edition as of the date of the NFPA issuance of this document.

5-1.1 NFPA Publications.

National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.

NFPA 10, *Standard for Portable Fire Extinguishers*, 1990 edition

NFPA 31, *Standard for the Installation of Oil-Burning Equipment*, 1992 edition

NFPA 54, *National Fuel Gas Code*, 1992 edition

NFPA 58, *Standard for the Storage and Handling of Liquefied Petroleum Gases*, 1992 edition

NFPA 70, *National Electrical Code*, 1993 edition

NFPA 72, *Standard for the Installation, Maintenance, and Use of Protective Signaling Systems*, 1990 edition

NFPA 82, *Standard on Incinerators, Waste, and Linen Handling Systems and Equipment*, 1990 edition

NFPA *101*, *Life Safety Code*, 1991 edition

NFPA 501C, *Standard on Recreational Vehicles*, 1990 edition

NFPA 1221, *Standard for the Installation, Maintenance, and Use of Public Fire Service Communication Systems*, 1991 edition

NFPA 1901, *Standard for Pumper Fire Apparatus*, 1991 edition

NFPA 1963, *Standard for Screw Threads and Gaskets for Fire Hose Connections*, 1985 edition

5-1.2 Other Publications.

5-1.2.1 U.S. Government Publication. U.S. Government Printing Office, Superintendent of Documents, Washington, DC 20402.

Title 49, *Code of Federal Regulations, October 1, 1990*

5-1.2.2 ASME Publication. American Society of Mechanical Engineers, 345 East 47th Street, New York, NY 10017.

ASME Boiler and Pressure Vessel Code, 1989

5-1.2.3 ASTM Publications. American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103-1187.

ANSI A119.5-88, *Standards for Park Trailers*

ASTM A254-91, *Standard Specification for Copper Brazed Steel Tubing*

ANSI/ASTM A539-Rev A-90, *Standard Specification for Electric-Resistance-Welded Coiled Steel Tubing for Gas and Fuel Oil Lines*

ASTM B88-89, *Specification for Seamless Copper Water Tube*

ASTM B280-88, *Specification for Seamless Copper Tubing for Air Conditioning and Refrigeration Field Service*

ASTM 2513-Rev C-90, *Thermoplastic Gas Pressure Pipe, Tubing and Fittings*

ASTM 2517-81, *Reinforced Epoxy Resin Gas Pressure Pipe and Fittings*

5-1.2.4 UL Publication. Underwriters Laboratories, Inc., 333 Pfingsten Road, Northbrook, IL 60062.

UL 80-80, *Steel Inside Tank for Oil Burner Fuel*

Appendix A

This Appendix is not a part of the requirements of this NFPA document, but is included for information purposes only.

A-1-2 Approved.

The National Fire Protection Association does not approve, inspect or certify any installations, procedures, equipment, or materials nor does it approve or evaluate testing laboratories. In determining the acceptability of installations or procedures, equipment or materials, the authority having jurisdiction may base acceptance on compliance with NFPA or other appropriate standards. In the absence of such standards, said authority may require evidence of proper installation, procedure or use. The authority having jurisdiction may also refer to the listings or labeling practices of an organization concerned with product evaluations which is in a position to determine compliance with appropriate standards for the current production of listed items.

A-1-2 Authority Having Jurisdiction.

The phrase “authority having jurisdiction” is used in NFPA documents in a broad manner since jurisdictions and “approval” agencies vary as do their responsibilities. Where public safety is primary, the “authority having jurisdiction” may be a federal, state, local or other regional department or individual such as a fire chief, fire marshal, chief of a fire prevention bureau, labor department, health department, building official, electrical inspector, or others having statutory authority. For insurance purposes, an insurance inspection department, rating bureau, or other insurance company representative may be the “authority having jurisdiction.” In many circumstances the property owner or his designated agent assumes the role of the “authority having jurisdiction”; at government installations, the commanding officer or departmental official may be the “authority having jurisdiction.”

A-1-2 Listed.

The means for identifying listed equipment may vary for each organization concerned with product evaluation, some of which do not recognize equipment as listed unless it is also labeled. The “authority having jurisdiction” should utilize the system employed by the listing organization to identify a listed product.

A-1-2 Manufactured Home.

Manufactured homes were formerly referred to as “mobile homes” or “trailer coaches.”

A-2-1.1

Gas piping systems (natural gas, manufactured gas, liquefied petroleum gas in the vapor phase, liquefied petroleum gas-air mixtures, or mixtures of these gases) owned, operated, and maintained by a public utility are exempt from the provisions of this standard but are required to conform to 49 CFR, Part 192. (*See 2-3.1.1*.)

A-2-2.3.2 Manufactured home electrical service equipment should not be considered a source of ignition where it is not enclosed in the same compartment with a gas meter.

A-2-3.1.1 The Natural Gas Pipeline Safety Act of 1979 has the effect of requiring that all gas distribution system operators must adhere to the referenced title. Any master-metered gas distribution system through which a manufactured home community is supplied gas and that, in turn, distributes the gas to the ultimate users (tenants) is defined as a gas distribution system within the context of the federal regulations. Owners of master-metered housing projects or manufactured home communities accordingly are defined as “gas distribution system operators.”

Attention is also called to 49 CFR, Part 191, prescribing requirements for the reporting of gas leaks that are not intended by the operator.

Code of Federal Regulations, Title 49, Transportation, Parts 100-199, revised as of October 1, 1990, is available from the Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402. The American Society of Mechanical Engineers publishes the ASME *Guide for Gas Transmission and Distribution Piping Systems*, which contains CFR, Title 49, Part 192, along with other useful technical information.

The Handbook on Natural Gas Pipeline Safety in Residential Areas Served by Master Meters is published by the Superintendent of Documents, U.S. Government Printing Office. It was developed under contract for the U.S. Department of Housing and Urban Development HUD-PDR-124 November 1975) and is specifically aimed at providing "a timely and comprehensive safety guide for architects and engineers involved in the planning and design phases of multifamily projects and manufactured home parks."

A-2-4.1

The flexible connector should be installed to provide some slack.

A-2-4.3

Such protection may consist of posts, fencing, or other permanent barriers.

A-2-4.6.1 These provisions do not apply to centralized oil distribution systems (*see 2-3.5 and 2-6.2 of this standard*). See also NFPA 31, *Standard for the Installation of Oil-Burning Equipment*.

A-4-2.2

This requirement is to preclude possible damages to such underground services by the use of ground anchors, installations of skirting (underfloor enclosures), plantings, foundations for steps at access doors, etc.

A-4-3.4.1 See NFPA 71, *Standard for the Installation, Maintenance, and Use of Signaling Systems for Central Station Service*, or NFPA 72, *Standard for the Installation, Maintenance, and Use of Protective Signaling Systems*, for other suitable types of fire protective signaling systems.

A-4-3.6.3 It is recommended that each building owner provide a listed portable fire extinguisher suitable for handling incipient fire in the building. A listed extinguisher labeled as suitable for class A, B, and C fires (multipurpose dry-chemical-type) is recommended. The provision on each site of a $^3/_4$-in. (19-mm) nominal valved water outlet designed for connecting a $^3/_4$-in. (19-mm) nominal female swivel hose connection for fire suppression use is desirable where practical and if protected against freezing.

Appendix B Manufactured Home Community Action for Fire Safety

This Appendix is not a part of the requirements of this NFPA document, but is included for information purposes only.

B-1 Purpose.

The purpose of this appendix is to give fire safety guidance for the manufactured home community.

B-2 Responsibilities of the Community Management.

Community management should prepare the type of material detailed herein with the cooperation of the responsible local fire protection authority.

Community management should be responsible for instructing staff in the use of fire protection equipment and defining specific duties in the event of fire.

The objective is to give information to the community's manufactured home owner/occupants and to encourage their cooperation in the protection of life and property from fire.

How to Report a Fire. Give specific instructions to owners on how to report a fire including: name of manufactured home community, its location, and identification of involved manufactured home site.

Utility Services. The connecting and disconnecting of water, fuel, and electrical services should be made only by authorized persons, as determined by park management. Should these services be interrupted, telephone or notify __________ for water, __________ for fuel, and __________ for electrical.

B-2.1 Care and Maintenance of Equipment.

Fire Fighting Equipment. Portable fire extinguishers (and/or other fire fighting equipment) are maintained on the premises and the nearest emergency equipment is located ______________________________.

NOTE: Give full directions as to their location.

Laundry Rooms. Clothes dryers should be cleaned periodically by management to remove combustible material, including lint. A sign should be placed in a conspicuous place warning of the fire hazard in the placement of plastics in dryers and warning against the use of flammable liquids as cleaning agents.

Recreation Buildings. Management should instruct staff and community residents in the proper use of appliances in community buildings and provide a list of these instructions near each appliance.

Appendix C Responsibilities of the Manufactured Home Resident

This Appendix is not a part of the requirements of this NFPA document, but is included for information purposes only.

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The resident should comply with all applicable requirements of this standard and should maintain his/her manufactured home site, its facilities, and its equipment in good repair and in a firesafe condition.

Procedures in Case of Fire. In case of fire in your home, the home owner should do these things in the following order:

(1) Get all occupants out of the home.

(2) Call the fire department or sound the alarm. The important thing to do is to get professional fire fighters to the fire as promptly as possible.

Fire Conditions. Home owners should aid the management in keeping the area free of fire hazards by notifying the management when they recognize unsafe conditions. Constant vigilance is necessary to maintain the premises free from fire at all times.

LP-Gas Containers. In addition to mounted containers, a home may have two additional vessels installed on the lot. The home may be served by either the vehicle containers or vessels on the lot but not by both at the same time. LP-Gas containers should be installed in accordance with the applicable provisions of NFPA 58, *Standard for Storage and Handling of Liquefied Petroleum Gases*.

Charging of Vessels. Liquefied petroleum gas vessels should be charged in accordance with the applicable provisions of NFPA 58, *Standard for Storage and Handling of Liquefied Petroleum Gases*.

Prohibited Location of Vessel. No liquefied petroleum gas vessel should be stored or located inside of or beneath any storage cabinet, cabana, awning, carport, ramada, home, or any other structure in a community.

Empty LP-Gas Containers. Owners should not place empty LP-Gas containers under their homes. Empty containers should be left in place if there is more than one container. If the manufactured home's LP-Gas supply is limited to one container and a replacement has been secured, any empty fuel container should be stored in the area designated for such storage.

Home Inspections. If an owner would like to have a voluntary inspection of his/her home, he/she should notify the fire department.

Traffic Regulations. Operators of vehicles should observe the posted signs and should keep all designated fire lanes and access to fire hydrants open at all times.

Marking. Each home site should be marked for identification. Such a marker should be easily readable from the street servicing the site.

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Periodic inspections of the enclosed space are recommended to ensure that all utility and other connections are secure and that no fire hazards exist.

Appendix D Referenced Publications

D-1

The following documents or portions thereof are referenced within this standard for informational purposes only and thus should not be considered part of the requirements of this document. The edition indicated for each reference is the current edition as of the date of the NFPA issuance of this document.

D-1.1 NFPA Publications.

National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA

02269-9101.

NFPA 31, *Standard for the Installation of Oil-Burning Equipment*, 1992 edition

NFPA 71, *Standard for the Installation, Maintenance, and Use of Signaling Systems for Central Station Service*, 1989 edition

NFPA 72, *Standard for the Installation, Maintenance, and Use of Protective Signaling Systems*, 1990 edition

D-1.2 U.S. Government Publication.

U.S. Government Printing Office, Superintendent of Documents, Washington, DC 20402.

Title 49, *Code of Federal Regulations*, 1990

Handbook on Natural Gas Pipeline Safety in Residential Areas Served by Master Meters, 1975 edition

D-1.3 ASME Publication.

345 E. 47th Street, New York, NY 10017.

Guide for Gas Transmission and Distribution Piping Systems, 1986

NFPA 501C

1996 Edition

Standard on Recreational Vehicles

1996 Edition

This edition of NFPA 501C, *Standard on Recreational Vehicles*, was prepared by the Technical Committee on Recreational Vehicles and acted on by the National Fire Protection Association, Inc., at its Fall Meeting held November 13-15, 1995, in Chicago, IL. It was issued by the Standards Council on January 12, 1996, with an effective date of February 2, 1996, and supersedes all previous editions.

Changes other than editorial are indicated by a vertical rule in the margin of the pages on which they appear. These lines are included as an aid to the user in identifying changes from the previous edition.

This edition of NFPA 501C was approved as an American National Standard on February 2, 1996.

Origin and Development of NFPA 501C

Period 1937-1970

The earliest activity of the NFPA in the field of mobile homes and recreational vehicles was the formation of an NFPA Committee on Trailers and Trailer Camps in 1937. Its first standard was adopted in 1940. That edition remained unchanged until after World War II when a 1952 revision was approved. These editions were entitled “Standards for Fire Prevention and Fire Protection in Trailer Coaches and Trailer Courts.” In 1960 the Association acted to approve a revised version, dividing the text into two parts — one designated No. 501A covering trailer courts and the other, No. 501B, covering trailer coaches. In 1961 a new edition of 501B was adopted under the title “Standard for Fire Prevention and Fire Protection in Mobile Homes and Travel Trailers”; and in 1963 a revision of same was approved. Revisions of both NFPA Nos. 501A and 501B were acted upon in 1964.

In the early 1960s the Mobile Homes Manufacturers Association (MHMA) and the Trailer Coach Association (TCA) prepared, under the aegis of the American Standards Association (now ANSI), two standards that were subsequently approved as the American Standard Installations of Plumbing, Heating and Electrical Systems in Travel Trailers (A119.2-1963) and a similar text for Mobile Homes (A119.1-1963). In 1964 the two separate standards activities were consolidated with the approval of the United States of America Standards Institute (formerly American Standards Association and subsequently ANSI) as of October 16, 1964. In 1969 the Recreational Vehicle Institute (RVI) was added to the MHMA, NFPA, and TCA as a fourth cosponsor of the project. The first *Standard for Recreational Vehicles* developed under the consolidated efforts of NFPA, MHMA, TCA, and RVI was that approved by NFPA in 1970 and by ANSI in 1971. This replaced ASA Standard A119.2-1963.

The Mobile Homes Manufacturers Association and the Trailer Coach Association were merged in 1975 to become the Manufactured Housing Institute. The Recreational Vehicle Institute was redesignated the Recreation Vehicle Industry Association also in 1975, absorbing the Recreational Vehicle Division of the Trailer Coach Association.

1970-1977

Previous editions of this standard were published in 1970 (approved by NFPA May 20, 1970), 1972 (approved by NFPA May 16, 1972, and approved by ANSI on April 19, 1973), 1974 (approved by NFPA May 21, 1974, and approved by ANSI on February 5, 1975), and 1976 (adopted by NFPA November 17, 1976).

The 1977 edition of the standard was developed by the Sectional Committee on Recreational Vehicles, processed through the Correlating Committee on Mobile Homes and Recreational Vehicles, approved by the National Fire Protection Association at its 1977 Annual Meeting held in Washington, DC, May 16-19, and approved by ANSI on October 18, 1977. The *only* substantive changes since the previous (1975) edition were revisions to Part 8 on mobile home park electrical systems. Some editorial revisions were accomplished in other parts and references to other standards referenced herein were updated.

1977-present

Subsequent to the 1977 edition, the NFPA withdrew as a cosponsor of the ANSI project and established its own project covering only the subject of fire safety for recreational vehicles.

The 1982 edition of the standard was produced by this newly formed Committee (June 20, 1979) charged with the responsibility of developing a standard for fire safety for recreational vehicles and recreational vehicle parks. Therefore, this edition and the 1982 edition both exclude all sections of the previous editions not considered within the Committee Scope. Notably excluded are sections dealing with plumbing. Modifications have also been made in sections dealing with heating, fire, and life safety, and include conformance with the NFPA *Manual of Style*.

The 1986 edition included minor changes in all chapters, and a new Chapter 5 to replace Appendix C so that all mandatory provisions are contained in the body of the document.

The 1990 edition contained minor revisions to Chapters 2 and 3 and one new definition added to Chapter 1.

A few definitions were revised in the 1993 edition, and minor changes were incorporated in Chapters 2 and 3, including the size of alternate exits.

Minor changes have been made in all chapters of this 1996 edition, including a new section on clothes dryers, 2-6.8; the requirement for an LP-Gas detector, 3-4.7; and the expansion of provisions for recreational vehicles used for transporting or storing internal combustion engine vehicles, 3-4.8 (formerly 3-4.7).

Notice

Requirements for plumbing are developed by the ANSI A119 Committee of which the Recreation Vehicle Industry Association is Secretariat. Those requirements and the fire safety requirements of NFPA 501C are published and distributed under one cover as ANSI A119.2/NFPA 501C by ANSI, NFPA, and RVIA.

Technical Committee on Recreational Vehicles

Mark Luttich, *Chair*
Nebraska Dept. of Health, NE

Bruce A. Hopkins, *Secretary*
Recreation Vehicle Industry Assn., VA

Donald D. Bartz, Winnebago Industries, Inc., IA

Joseph M. Bloom, Bloom Fire Investigation, OR

Orville H. Cummings, Florida Bureau of Mobile Home & Rec Vehicle Const., FL

Daniel F. Fitzgerald, State of California, CA

John P. Harvey, State of Washington, WA

Ralph E. Herzler, Majara Corp., MI

Jon O. Jacobson, Jacobson Engr, WA

George E. Kiefer, State of Arizona, AZ

Shawn D. MacGregor, Terralab Engr Int'l, UT

John Pabian, Underwriters Laboratories Inc., IL

Homer Staves, Kampgrounds of America, Inc., MT

Raymond F. Tucker, RADCO, CA

Gary Wight, Park Washington, WA
Rep. Nat'l Assn. of RV Parks & Campgrounds

Robert E. Wozniak, Fleetwood Enterprises, Inc., CA

Patrick Yee, Canadian Standards Assn., ON

Alternates

Christopher J. Bloom, CJB Fire Consultants, OR
(Alt. to J. M. Bloom)

James W. Finch, Kampgrounds of America, Inc., MT
(Alt. to H. Staves)

Kent Perkins, Recreation Vehicle Industry Assn., VA
(Alt. to B. A. Hopkins)

Toby Pimental, State of Arizona, AZ
(Alt. to G. E. Kiefer)

James R. Thiel, Underwriters Laboratories Inc., IL
(Alt. to J. Pabian)

Richard Ortisi-Best, NFPA Staff Liaison

This list represents the membership at the time the Committee was balloted on the text of this edition. Since that time, changes in the membership may have occurred.

NOTE: Membership on a Committee shall not in and of itself constitute an endorsement of the

Association or any document developed by the Committee on which the member serves.

Committee Scope: This Committee shall have primary responsibility for documents on the fire safety criteria for recreational vehicles and recreational vehicle parks.

NFPA 501C
Standard on
Recreational Vehicles

1996 Edition

NOTICE: An asterisk (*) following the number or letter designating a paragraph indicates explanatory material on that paragraph in Appendix A.
Information on referenced publications can be found in Chapter 5.

Chapter 1 General

1-1 Introduction.

1-1.1 Need for Standard.

Those members of the engineering profession and others associated with the design, manufacturing, and inspection of recreational vehicles have been aware of the need for uniform technical standards leading to the proper use of this special type of equipment. They also have recognized that, because of conditions of transport, size, and use, existing standards for motor vehicles or permanent buildings are not completely applicable to recreational vehicles. It is with these factors in mind that this standard has been developed.

1-1.2 Basis for Standard.

Much of the material in this standard has been taken from, or is based on, nationally recognized standards for fire and life safety. Applicable standards are shown in Chapter 5.

1-2 Scope.

1-2.1 Applicability.

This standard shall cover fire and life safety criteria for recreational vehicles considered necessary to provide a reasonable level of protection from loss of life from fire and explosion. They reflect situations and the state of the art prevalent at the time the standard was issued.

Unless otherwise noted, it shall not be intended that the provisions of this document be applied to facilities, equipment, structures, or installations that were existing or approved for construction or installation prior to the effective date of the document, except in those cases where it is determined by the authority having jurisdiction that the existing situation involves a distinct hazard to life or adjacent property.

1-2.2 Limitations.

This standard shall not be intended as a design specification or an instruction manual.

1-2.3 Alternate Materials, Equipment, and Procedures.

The provisions of this standard shall not be intended to prevent the use of any material, method of construction, or installation procedure not specifically prescribed by this standard, provided any such alternate is acceptable to the authority having jurisdiction. The authority having jurisdiction shall require that sufficient evidence be submitted to substantiate any claims made regarding the safety of such alternates.

1-2.4 Differing Standards.

Wherever nationally recognized standards and this standard differ, the requirements of this standard shall apply.

1-2.5 U.S. Federal Regulations.

Federal regulations under the National Highway Traffic Safety Administration can supersede all or part of this standard as applied to any category of regulated motor vehicles.

1-3 Definitions.*

Approved.* Acceptable to the authority having jurisdiction.

Authority Having Jurisdiction.* The organization, office, or individual responsible for approving equipment, an installation, or a procedure.

Axle Height. The distance to the lower connection of the axle spindle assembly and the outboard end of the lower control arm (lever ball joint or kingpin), excluding shock mounting, grease fitting, or similar component. A single or dual beam axle is measured at the lowest point of that beam axle at the spring location.

Camping Trailer. A vehicular portable unit mounted on wheels and constructed with collapsible partial side walls that fold for towing by another vehicle and unfold at the campsite to provide temporary living quarters for recreational, camping, or travel use. (*See definition of Recreational Vehicle*.)

Compartment. A completely enclosed volume designed to provide for a separate area.

Connection, Gas Supply. The terminal end or connection where a gas supply connector is attached.

Connector, Gas Supply. Tubing or pipe connecting the recreational vehicle to the gas supply source.

Dry Weight. The weight of the completed finished vehicle when factory-equipped, without fluids.

Fifth Wheel Trailer. A vehicular unit, mounted on wheels, designed to provide temporary living quarters for recreational, camping, or travel use, of such size or weight as not to require special highway movement permit(s), of gross trailer area not to exceed 400 ft^2 (37.2 m^2) in the set-up mode, and designed to be towed by a motorized vehicle that contains a towing mechanism that is mounted above or forward of the tow vehicle's rear axle. (*See definition of Recreational Vehicle.*)

Frame. Chassis rail and any addition thereto of equal or greater strength.

Fuel System. Any arrangement of pipe, tubing, fittings, connectors, tanks, controls, valves, and devices designed and intended to supply or control the flow of fuel.

Gross Trailer Area.* The total plan area measured to the maximum horizontal projections of exterior walls in the set-up mode.

Heat Appliance. An appliance for comfort heating of a recreational vehicle or for water heating.

Heat-Producing Appliance. An appliance that produces heat by utilizing electric energy or by burning fuel.

Identified (as applied to Equipment). Recognizable as suitable for the specific purpose, function, use, environment, application, etc., where described in a particular requirement.

Interior Finish. The exposed interior surface in combination with the substrate to which it is applied. Interior finish shall include any material (such as paint, wallpaper, decorative panels, etc.) that is affixed to such surfaces by permanent or semi-permanent means.

Labeled. Equipment or materials to which has been attached a label, symbol, or other identifying mark of an organization that is acceptable to the authority having jurisdiction and concerned with product evaluation that maintains periodic inspection of production of labeled equipment or materials and by whose labeling the manufacturer indicates compliance with appropriate standards or performance in a specified manner.

Liquefied Petroleum Gas (LP-Gas and LPG). Any material having a vapor pressure not exceeding that allowed from commercial propane composed predominantly of the following hydrocarbons, either by themselves or as mixtures: propane, propylene, butane (normal butane or iso-butane), and butylene (including isomers).

Listed.* Equipment or materials included in a list published by an organization acceptable to the authority having jurisdiction and concerned with product evaluation that maintains periodic inspection of production of listed equipment or materials and whose listing states either that the equipment or material meets appropriate standards or has been tested and found suitable for use in a specified manner.

Motor Home. A vehicular unit designed to provide temporary living quarters for recreational, camping, or travel use, built on or permanently attached to a self-propelled motor vehicle chassis or on a chassis cab or van that is an integral part of the completed vehicle. (*See definition of Recreational Vehicle.*)

Recreational Park Trailer. See ANSI A119.5, *Standard for Park Trailers*.

Recreational Vehicle. A vehicular-type unit primarily designed as temporary living quarters for recreational, camping, travel, or seasonal use that either has its own motive power or is mounted on, or towed by, another vehicle. The basic entities are: camping trailer, fifth wheel trailer, motor home, park trailer, travel trailer, and truck camper. (*See individual definitions.*)

Shall. Indicates a mandatory requirement.

Travel Trailer. A vehicular unit, mounted on wheels, designed to provide temporary living quarters for recreational, camping, or travel use, of such size or weight as not to require special highway movement permits when towed by a motorized vehicle, and of gross trailer area less than 320 ft^2 (29.7 m^2). (*See definition of Recreational Vehicle*.)

Truck Camper. A portable unit constructed to provide temporary living quarters for recreational, travel, or camping use, consisting of a roof, floor, and sides, designed to be loaded onto and unloaded from the bed of a pickup truck. (*See definition of Recreational Vehicle.*)

1-4 Exterior Labels Required by this Standard.

Exterior labels required by Chapters 2 and 3 shall be made of etched, metal-stamped, or embossed brass, stainless steel, plastic laminates [0.005-in. (0.13-mm) min.], or anodized or alclad aluminum not less than 0.020 in. (0.5 mm) thickness. These labels shall be mounted by permanent attachment methods compatible with the surface to which they are applied. Other types of labels shall be permitted to be approved if there is adequate proof of permanency and comparable life expectancy to those types specified herein.

1-5 Electrical Requirements.

All electrical installations, systems, and equipment shall comply with Article 551, Part A, and other applicable sections of NFPA 70, *National Electrical Code*®.

1-6* Use of International System of Units (SI).

In some cases SI equivalents to U.S. units have been inserted in this standard. Where used, the conversions have been rounded to the number of digits commensurate with their intended precision. The way the SI units are used is in accordance with the NFPA *Manual of Style*. Alternate usage of U.S. and SI units to determine distance, size (capacity), or dimensions shall not be used to regulate same. Where SI equivalents are not given, it is because the U.S. units shall be employed by anyone enforcing this standard.

Chapter 2 Fuel Systems and Equipment

2-1 Quality of Design and Installation.

All design, construction, and workmanship shall be in conformance with accepted engineering practices.

2-2 LP-Gas Systems.

2-2.1 Maximum Container Capacities.

Where LP-Gas fuel utilization equipment is installed by the recreational vehicle manufacturer, the recreational vehicle shall be provided with:

(a) One but not more than three nonpermanently mounted DOT or ASME containers having individual water capacities of 105 lb (47.6 kg) maximum [approximately 45 lb (20.4 kg) LP-Gas capacity], or

(b) One or more permanently mounted ASME containers having a maximum aggregate water capacity of 200 gal (757 L) [approximately 712 lb (323 kg) LP-Gas capacity].

2-2.2 Construction of LP-Gas Containers.

DOT containers shall be constructed and marked in accordance with the specifications for LP-Gas containers of the U.S. Department of Transportation (DOT), the Rules for Construction of Unfired Pressure Vessels, Section VIII, Division 1, ASME *Boiler and Pressure Vessel Code*. ASME containers utilizing vapor withdrawal shall be constructed and marked in accordance with the rules for construction and shall have a design pressure of at least 312.5 psi (2155 kPa).

2-2.3 Location of LP-Gas Containers.

LP-Gas containers shall be in accordance with the following:

(a) LP-Gas containers shall not be installed nor shall provisions be made for installing or storing any LP-Gas containers, even temporarily, inside any recreational vehicle. Containers shall not be mounted on the exterior of the rear wall or the rear bumper of the vehicle.

Exception: New LP-Gas DOT containers that have never contained LP-Gas, supplied as original equipment, shall be permitted to be transported inside the vehicle.

(b) LP-Gas containers with their control valves shall be installed in compliance with one of the following:

1. In a recess or compartment other than on the roof that is vaportight to the inside of the recreational vehicle.

2. Mounted on the tongue or A frame of a travel or camping trailer or forward of the front bulkhead below the overhang of a fifth wheel travel trailer and not lower than the bottom of the trailer frame.

3. Mounted on the chassis or to the floor of a motor home or chassis-mount camper, provided neither the container nor its support is located ahead of the front axle. Containers mounted between the front and rear axles shall be installed with as much road clearance as practical but not lower than the front axle height. Containers mounted behind the rear axle of a motor home or chassis-mount camper shall be installed in such a manner that the bottom of the tank and any connection thereto shall not be lower than either the rear axle height (excluding the differential) or any section of the frame immediately to the rear of the tank, whichever is higher. All clearances shall be determined from the bottom of the container or from the lowest fitting, support, or attachment on the container or container housing, whichever is lower when all axles are simultaneously loaded to their gross axle weight rating.

2-2.4 Securing of LP-Gas Containers.

Containers shall be secured in place so they will not become dislodged when a load equal to eight times the container's filled weight is applied to the filled container's center of gravity in any direction. If the recreational vehicle is supplied with the containers not in place, the recreational vehicle manufacturer shall provide mounting instructions and required materials with the vehicle.

2-2.5 Shielding of LP-Gas Containers from Heat of Internal Combustion Engine Exhaust System Components.

LP-Gas containers located less than 18 in. (475 mm) from the exhaust system, the transmission, or a heat-producing component of the internal combustion engine, shall be shielded by a vehicle frame member or by a noncombustible baffle, with an air space on both sides of the frame member or baffle.

2-2.6 LP-Gas Container Enclosures.

2-2.6.1 Ventilation of Compartments Containing LP-Gas Containers. Compartments shall be ventilated at or near the top and at the extreme bottom to facilitate diffusion of vapors. The compartment shall be ventilated with at least two vents having an aggregate free area equal to at least 1 in.^{2} for each 7 lb (1 cm^2 per g) of the total LP-Gas fuel capacity of the container(s). The vents shall be equally distributed between the floor and ceiling of the compartment. If the lower vent is located in the access door or wall, the bottom edge of the vent shall be flush with the floor level of the compartment. The top vent shall be located in the access door or wall with the bottom of the vent within 12 in. (305 mm) of the ceiling of the compartment. Vents shall have an unrestricted discharge to the outside atmosphere. Doors or panels providing access to valves shall not be equipped with locks or require special tools to open.

2-2.6.2 Securing LP-Gas Container Housings. Doors, hoods, domes, housings (or portions of housings), and enclosures required to be removed or opened for replacement of containers shall incorporate means for clamping them firmly in place and preventing them from working loose during transit. Hoods or housings covering valves shall not be equipped with locks or require special tools to open.

2-2.6.3 Fastenings for LP-Gas Containers in Compartments. Container compartments or carriers shall be provided with hold-down fastenings complying with 2-2.4 for as many containers as the carriers or compartments are capable of holding.

2-2.6.4 Elimination of Ignition Sources. LP-Gas containers shall not be installed in compartments or under hoods or housings that contain flame- or spark-producing equipment.

2-2.7 LP-Gas Container Valves and Accessories.

2-2.7.1 Container Appurtenances. Appurtenances such as safety relief devices, container shutoff valves, automatic stop fill devices, back-flow check valves, internal valves, excess-flow check valves, liquid level gauges, pressure gauges, and pressure regulators shall be listed.

2-2.7.2 Location of Container Appurtenances. The manual control of the container's shutoff valve, the LP-Gas fill connection, and the liquid level outage valve of permanently installed ASME containers shall be located not more than 18 in. (457 mm) from the vehicle's outside wall. The LP-Gas fill connection and its liquid level outage valve shall be located in accordance with like requirements for LP-Gas safety relief devices (*see 2-2.8.3*).

Exception: Vehicles shall be permitted to be equipped with a remotely controlled normally closed electronic shutoff valve installed on the high pressure side of the LP-Gas regulator. A double back-flow valve shall be installed in the fill opening of the container. The remote fill connection, liquid level outage valve, and electronic shutoff valve control shall be located within 18 in. (45.7 cm) of the vehicle outside wall and shall be located in accordance with like requirements for LP-Gas safety relief devices (see 2-2.8.3).

2-2.7.3 Valves for Multiple LP-Gas Container Assembly System. Valves in a multiple LP-Gas container assembly system shall be arranged so that replacement of containers can be made without shutting off the flow of gas to the appliance(s).

NOTE: This provision is not to be construed as requiring an automatic changeover device.

2-2.7.4 Automatic Stop Fill Devices. Permanently installed containers shall be equipped with a listed automatic stop fill device.

2-2.7.5 Protection of LP-Gas Container Shutoff Valves. Container shutoff valves shall be protected as follows:

(a) By setting into a recess of the container to prevent possibility of their being struck if container is dropped upon a flat surface, or

(b) By a ventilated cap or collar, fastened to the container, capable of withstanding a blow from any direction equivalent to that of a 30-lb (13.6-kg) weight dropped 4 ft (1.2 m). Construction must be such that the blow will not be transmitted to the valve.

2-2.7.6 LP-Gas Regulators. Listed two-stage regulator(s) shall be supplied. Such regulator(s) shall have a capacity not less than the total input of all LP-Gas appliances installed in the recreational vehicle. The regulator(s) shall be mounted only in a position downward within 45 degrees of vertical and the diaphragm area being drained. Containers installed below floor level shall have the regulator(s) installed in a compartment that provides protection against the weather and wheel spray. The compartment shall be of sufficient size to permit tool operation for connection to and replacement of the regulator(s), shall be vaportight to the interior of the vehicle, shall have a 1 in.^{2} (6.5 cm^2) minimum vent opening to the exterior located within 1 in. (25 mm) of the bottom of the compartment, and shall not contain flame- or spark-producing equipment. The regulator vent outlet shall be at least 2 in. (51 mm) above the compartment vent opening.

Regulators installed elsewhere and not installed in compartments as specified above shall be equipped with a durable cover [that will not become brittle at temperatures as low as –40°F (–40°C)] designed to protect the regulator vent opening from sleet, snow, freezing rain, ice, mud, and wheel spray.

If the regulator is not mounted by the recreational vehicle manufacturer, instructions for proper installation shall be supplied.

2-2.7.7 LP-Gas Excess Flow Valves. A listed LP-Gas excess flow valve shall be provided in accordance with the following:

(a) The inlet or outlet of each container service valve of a permanently mounted container shall be equipped with such a listed excess flow valve or a listed POL (CGA 510) adapter with an integral excess flow valve.

(b) Vehicles with removable (DOT) type containers shall have furnished or installed a listed POL adapter with an integral listed excess flow valve.

2-2.8 LP-Gas Container and System Safety Devices.

2-2.8.1 LP-Gas Container Safety Relief Devices. DOT containers shall be provided with safety relief devices as required by the regulations of the U.S. Department of Transportation. ASME containers shall be provided with relief valves in accordance with 8-2.3(a)(4) of NFPA 58, *Standard for the Storage and Handling of Liquefied Petroleum Gases*. Safety relief valves shall have a direct communication with the vapor space of the vessel.

Listed manual tank shutoff valves (service valves) of ASME containers shall be equipped with an internal excess flow check valve designed to close automatically at rated flows of vapor specified by the manufacturer. Excess flow valves shall be designed with a bypass not to exceed a number 60 drill size opening to allow equalization of pressure.

2-2.8.2 Regulator Relief Device. Final stage regulators shall be equipped on the low pressure side with one or both of the following:

(a) A relief valve having a start-to-discharge pressure setting of not less than 1.7 times and not more than 3 times the delivery pressure of the regulator.

(b) A shutoff device that shuts the gas off at the inlet side when the downstream pressure reaches the overpressure limit of not less than 1.7 times and not more than 3 times the delivery pressure of the regulator. Such a device shall not open to allow flow of gas until it has been manually reset.

2-2.8.3 Discharge from LP Safety Relief Devices. Discharge from LP safety relief devices shall be located in accordance with the following:

(a) Discharge outlets shall be so located that the discharge from the safety relief device shall be not less than 3 ft (0.9 m) measured horizontally along the surface of the vehicle from any of the following located below the level of such discharge:

1. Openings into the recreational vehicle,
2. Fuel-burning appliance intake and exhaust vents, and
3. All internal combustion engine exhaust terminations.

Exception: Unventilated compartment doors containing either door or body side seals and entry doors not containing screens or openable windows below the level of the LP discharge outlet(s).

(b) The discharge from the outlet of the safety relief device on ASME containers shall not directly impinge on the vehicle fuel container(s), the exhaust system, any other part of the vehicle, or be directed into the interior of the vehicle.

(c) Where the relief device outlets are located in a compartment vaportight to the vehicle interior, discharge from these devices shall be considered to be located at the compartment vents and shall meet the location requirements of 2-2.8.3(a) above.

2-2.9 LP-Gas System Design and Service Line Pressures.

2-2.9.1 LP-Gas System Design. Systems shall be of the vapor-withdrawal type.

Exception: Liquid withdrawal systems are permitted to supply LP-Gas as engine fuel. See Section 2-11 for engine fuel installations.

2-2.9.2 LP-Gas Vapor Pressure Maximum. Vapor, at a pressure not over 14 in. water column (3.49 kPa), shall be delivered from the system into the gas appliance supply connection.

Exception: A fuel-burning appliance that operates at a pressure higher than 14 in. water column (3.49 kPa) shall be acceptable provided it meets all of the following:

(a) The appliance must provide for a separate fuel supply system or provide a means to prevent high pressure from entering the recreational vehicle’s low pressure system.

(b) The high-pressure fuel system shall be located entirely on the exterior of the vehicle or in a compartment that is vaportight to the vehicle’s interior.

(c) Exterior rated labels shall be permanently attached to the appliance or appliance compartment and at the fuel source in a visible location indicating:

1. the operating pressure;

2. any special precautions to be taken while servicing; and

3. a statement warning against connecting the appliance to any other fuel system or that fuel system to another appliance.

(d) The fuel system shall be tested at six times its working pressure prior to its installation and at its working pressure after installation.

(e) A two-stage regulator system is not required for the high- pressure system.

(f) The appliance is listed for RV use at the specified operating pressure.

2-2.9.3 Mounting of LP-Gas Containers. Container openings for vapor withdrawal shall be located in the vapor space when the container is in service or shall be provided with a suitable permanent internal withdrawal tube that communicates with the vapor space in or near the highest point in the container when it is mounted in service position with the vehicle on a level surface. ASME tanks shall have vapor withdrawal located midway between tank ends. Each container shall be permanently and legibly stamped to show the correct mounting position. Stamping shall be $^{1}/_{4}$ in. (6 mm) minimum letter height. The method of mounting in place shall be such as to minimize the possibility of an incorrect positioning of the container.

2-3 Fuel Oil Supply for Heat-Producing Appliances.

2-3.1 Gravity Flow Oil Tanks.

Oil tanks installed for gravity flow of oil to heating equipment shall be installed so that the top of the tank is no higher than 8 ft (2.4 m) above the appliance oil control and the bottom of the tank is no less than 18 in. (457 mm) above the appliance oil control.

2-3.2 Mounting of Automatic Pumps.

Listed automatic pumps (oil lifter) shall be mounted no higher than 8 ft (2.4 m) above the appliance oil control and not less than 18 in. (457 mm) above the appliance oil control.

2-3.3 Oil Supply Tank Affixed to Vehicle.

Oil supply tanks affixed to a recreational vehicle shall be so located as to require filling and draining on the outside and shall be securely fastened in position in a place readily available for inspection.

2-3.4 Oil Supply Tank Located in Vehicle Compartment.

If the oil supply tank is located in a recess or compartment of a recreational vehicle, the compartment shall be vaportight to the inside of the recreational vehicle; ventilated at the bottom to permit diffusion of vapors; and isolated from oil absorption material members. A tank so installed shall be provided with an outside fill and vent pipe and an approved liquid level gauge.

2-3.5 Oil Supply Tank Shutoff Valves.

A readily accessible, listed, manual shutoff valve shall be installed at the outlet of an oil supply tank. The valve shall be installed to close against the supply.

2-3.6 Oil Filters.

All oil tanks, except for integrally mounted tanks, shall be equipped with a listed oil filter or strainer located downstream from the tank shutoff valve. The fuel oil filter or strainer shall contain a sump with a drain for the entrapment of water.

2-4 Fuel Gas Piping Systems.

2-4.1 General.

The requirements of this section shall govern the installation of all fuel gas piping intended for carrying gas in the vapor state attached to any recreational vehicle. None of the requirements listed in this section shall apply to the piping supplied as a part of a listed appliance. Liquid withdrawal piping shall comply with the requirements of NFPA 58, *Standard for the Storage and Handling of Liquefied Petroleum Gases (see Sections 2-4 and 3-2.8)*.

2-4.2 Gas Piping System Materials.

Materials used for the installation, extension, alteration, or repair of any gas piping system shall be new and free from defects or internal obstructions. It shall not be permitted to repair defects in gas piping or fittings. Inferior or defective materials shall be removed and replaced with acceptable material. The system shall be made of materials having a melting point of not less than 1450°F (788°C), except as provided in 2-4.5, 2-4.6, and 2-4.12, or of materials (used in piping or fittings) listed for the specific use intended. They shall be permitted to consist of one or more of the following materials:

(a) Gas pipe shall be steel or wrought-iron pipe complying with ANSI B36.10M, *Welded and Seamless Wrought Steel Pipe*. Threaded copper or brass pipe in iron pipe sizes shall be permitted to be used.

(b) Fittings for gas piping shall be wrought iron, malleable iron, steel, or brass (containing not more than 75 percent copper). Brass flare nuts shall be stress relieved or of the forged type.

(c) Copper tubing shall be annealed Type K or L, conforming to ASTM B 88, *Standard Specifications for Seamless Copper Water Tube*, or shall comply with ASTM B 280, *Specifications for Seamless Copper Tube for Air Conditioning and Refrigeration Field Service*. Where used on systems designed for natural gas, such tubing shall be internally tinned.

(d) Seamless brass tubing shall be composed of not more than 75 percent copper (cartridge brass 70 percent) and shall have a minimum thickness of 0.030 in. (0.76 mm).

(e) Steel tubing shall be constructed in accordance with ASTM A 539, *Standard Specifications for Electric-Resistance Welded Coiled Steel Tubing for Gas and Fuel Oil Lines*, and shall be externally corrosion-protected.

(f) Flexible nonmetallic tubing or hose shall be either listed and used with listed fittings or part of a listed assembly.

2-4.3 Gas Piping Design.

Each recreational vehicle requiring fuel gas for any purpose shall be equipped with a gas piping system that is designed for LP-Gas only or with a natural gas piping system acceptable for LP-Gas.

2-4.4 Gas Pipe Sizing.

Gas piping systems shall be sized so that the pressure drop to any appliance inlet connection from the gas supply connection or connections, where all appliances are in operation at maximum capacity, is not more than 0.5 in. water column (0.125 kPa) where used with natural gas if the system is designed for both natural and LP-Gas, or where used with LP-Gas if the system is designed for LP-Gas only. Conformance can be determined on the basis of test, or the gas piping system can be sized in accordance with one of the following tables [2-4.4(a) through 2-4.4(d)], or other approved method. The natural gas supply connection shall be not less than $^{3}/_{4}$ in. nominal pipe size. (*See Appendix B for further guidance on how to calculate gas piping size.*)

Table 2-4.4(a) Sizing of Low-Pressure Gas Piping Systems Maximum Capacity of Iron Pipe Sizes in Thousands of Btu per Hour Combination of LP-Gas/Natural Gas System

Nominal Iron Pipe Size (I.D.)		Length of Pipe in ft (m)									
in.	**(mm)**	**10**	**(3.1)**	**15**	**(4.6)**	**20**	**(6.1)**	**25**	**(7.6)**	**30**	**(9.2)**
1/4	(6)	43	(13.1)	33	(10)	29	(8.8)	27	(8.2)	24	(7.3)
3/8	(10)	95	(29)	77	(23.5)	65	(19.8)	57	(17.4)	52	(15.9)
1/2	(13)	175	(53)	135	(41)	120	(37)	108	(33)	97	(29.6)
3/4	(19)	360	(110)	279	(85)	250	(76)	225	(69)	200	(61)
1	(25)	680	(207)	536	(163)	465	(142)	404	(123)	375	(114)

Table 2-4.4(b) Sizing of Low-Pressure Gas Piping Systems Maximum Capacity of Semi-Rigid Tubing in Thousands of Btu per Hour Combination of LP-Gas/Natural Gas System

Tubing Size				Length of Pipe in ft (m)									
in.		**(mm)**		**10**	**(3.1)**	**15**	**(4.6)**	**20**	**(6.1)**	**25**	**(7.6)**	**30**	**(9.2)**
O.D.	**I.D.**	**O.D.**	**I.D.**										
3/8	1/4	(10)	(6)	27	(8.2)	21	(6.4)	18	(5.5)	16	(4.9)	15	(4.6)
1/2	3/8	(13)	(10)	56	(17.1)	42	(12.8)	38	(11.6)	34	(10.4)	31	(9.5)
5/8	1/2	(16)	(13)	113	(34)	86	(26.2)	78	(23.8)	70	(21.3)	62	(18.9)
3/4	5/8	(19)	(16)	197	(60)	157	(48)	136	(41)	122	(37)	109	(33)
7/8	3/4	(22)	(19)	280	(85)	227	(69)	193	(59)	172	(52)	155	(47)

Table 2-4.4(c) Sizing of Low-Pressure Gas Piping Systems Maximum Capacity of Iron Pipe Sizes in Thousands of Btu per Hour LP-Gas System

Nominal Iron Pipe Size (I.D.)	Length of Pipe in ft (m)

in.	(mm)	10	(3.1)	15	(4.6)	20	(6.1)	25	(7.6)	30	(9.2)
1/4	(6)	67	(20.4)	52	(15.9)	46	(14)	41	(12.5)	37	(11.3)
3/8	(10)	147	(45)	112	(34)	101	(31)	87	(26.5)	81	(24.7)
1/2	(13)	275	(84)	212	(65)	189	(58)	166	(51)	152	(46)
3/4	(19)	567	(173)	500	(152)	393	(120)	338	(103)	315	(96)
1	(25)	1071	(326)	1005	(306)	732	(223)	667	(203)	590	(180)

Table 2-4.4(d) Sizing of Low-Pressure Gas Piping Systems Maximum Capacity of Semi-Rigid Tubing in Thousands of Btu per Hour LP-Gas System

Tubing Size										Length of Pipe in ft (m)			
in.		(mm)		10	(3.1)	15	(4.6)	20	(6.1)	25	(7.6)	30	(9.2)
O.D.	I.D.	O.D.	I.D.										
3/8	1/4	(10)	(6)	39	(11.9)	32	(9.8)	26	(7.9)	23	(7)	21	(6.4)
1/2	3/8	(13)	(10)	92	(28.1)	72	(21.9)	62	(18.9)	56	(17.1)	50	(15.3)
5/8	1/2	(16)	(13)	199	(61)	159	(49)	131	(40)	118	(36)	107	(33)
3/4	5/8	(19)	(16)	329	(100)	249	(76)	216	(66)	193	(59)	181	(55)
7/8	3/4	(22)	(19)	501	(153)	380	(116)	346	(106)	300	(91)	277	(84)

2-4.5 Joints for Gas Pipe.

Pipe joints in the piping system, unless welded or brazed, shall be screw joints that comply with ANSI B1.20.1, *Pipe Threads, General Purpose (Inch)*. Right and left nipples or couplings shall not be used. Unions, if used, shall be of the ground joint type. The material used for welding or brazing pipe connections shall have a melting temperature in excess of 1000°F (538°C).

2-4.6 Gas Tubing Joints.

Tubing joints shall be made with a single or double flare of 45 degrees conforming to SAE J 533, *Flares for Tubing, Standard*, as recommended by the tubing manufacturer or by means of listed vibration-resistant fittings, or the joints shall be brazed with a material having a melting point exceeding 1000°F (538°C). Brazing alloys shall not contain phosphorous. Sealants shall not be used on tubing joints. Ball sleeve or one-piece internal compression-type tubing fittings shall not be used. (*See 2-5.5.*)

2-4.7 Pipe Joint Materials.

Threaded joints shall be made up tight with approved pipe joint material, insoluble in liquefied petroleum gas, that shall be applied to the male threads only.

2-4.8 Routing and Protection of Tubing.

Tubing shall not be run inside walls, floors, partitions, or roof except that $^1/_4$ in. O.D. tubing shall be permitted to be concealed provided it is enclosed with a metallic covering of thickness equivalent to the thickness of the tubing enclosed. Where tubing passes through walls, floors, partitions, roofs, or similar installations, such tubing shall be protected by the use of weather-resistant grommets that shall fit snugly both the tubing and the hole through which the tubing passes.

2-4.9 Restrictions on Concealing Joints in Gas Piping or Tubing.

Pipe or tubing joints shall not be located in any floor, wall, partition, or concealed construction space. Pipe and tubing joints shall be permitted to be located in storage areas below the floor if they are located within 2 in. (50.8 mm) of the compartment's ceiling with the tubing joints protected from physical damage. Pipe joints shall be permitted to be located below the 2-in. (50.8-mm) requirement if protected from physical damage. Unprotected tubing shall not be located in storage areas below the floor level.

2-4.10 Gas Supply Connection Location.

For LP-Gas only systems and for combination LP-Gas and natural gas systems, the supply connection shall be located at the container location. An additional supply connection shall be permitted to be installed, located on the left (road) side, or at the rear left of the longitudinal center of the vehicle, within 18 in. (457 mm) of the outside wall. Combination LP-Gas and natural gas additional supply connections shall be within 15 ft (4.6 m) of the rear of the vehicle.

2-4.11 Gas Supply Connections.

2-4.11.1 Natural Gas Supply Connectors. A listed minimum $^1/_2$-in. (12.7-mm) nominal (I.D.) gas supply connector, with $^3/_4$-in. (19-mm) NPT terminal fittings, 6 ft (1.8 m) in length, shall be supplied by the manufacturer where the fuel gas piping system is designed for the use of natural gas.

2-4.11.2 LP-Gas Supply Connectors. Connectors used in LP-Gas systems shall be listed as conforming to UL 569, *Standard for Pigtails and Flexible Hose Connectors for LP-Gas*.

2-4.11.3 High-Pressure LP-Gas Connections. High-pressure LP-Gas connections shall be in accordance with the following:

(a) If the regulator is not directly connected to a permanently mounted container shutoff valve, it shall be connected to the container shutoff valve by a listed high-pressure flexible hose connector or by material conforming to 2-4.2.

(b) The connection between the shutoff valve of a container intended to be removed and mounted on the tongue (A frame) and a regulator mounted on a container support bracket shall be made with a listed high-pressure flexible hose connector.

(c) The connection between the shutoff valve of a container intended to be removed and mounted on the tongue (A frame) and a regulator permanently mounted other than as described in (b) above shall be made with a listed high-pressure flexible hose connector.

(d) The connection between the shutoff valve of a container intended to be removed and mounted within a compartment shall be made with a listed high-pressure flexible hose connector if the regulator is not directly attached to the shutoff valve.

2-4.11.4 Low-Pressure LP-Gas Connections. Low-pressure LP-Gas connections shall be in accordance with the following:

(a) The connection between a permanently mounted regulator or a regulator directly attached to a permanently mounted container and the gas supply system shall be made with a listed flexible hose connector or with material conforming to 2-4.2.

(b) The connection between a regulator mounted on a removable container support bracket or a regulator directly attached to the shutoff valve of a removable container and the gas supply system shall be made with a listed flexible hose connector.

2-4.12 Appliance Connections.

Except as provided herein, all gas-burning appliances shall be connected to the fuel piping with materials as provided in 2-4.2.

Exception: Where a flexible connector is required to connect a gas appliance, such as a fold-down range, the connector shall be a listed flexible hose connector conforming to UL 569, Standard for Pigtails and Flexible Hose Connectors for LP-Gas, and shall not pass through any floor or ceiling. They shall be permitted to pass through a wall or partition provided the entire length of the hose is readily available for visual inspection. Provision is made to protect against chaffing, and no part of the flexible connector is concealed in the hollow space of a wall or partition.

2-4.13 Gas Shutoff Valves.

Shutoff valves used in connection with gas piping shall be listed for use with LP-Gas and shall have nondisplaceable rotors.

2-4.14 Gas Inlet Cap.

2-4.14.1 For combination LP-Gas and natural gas systems, suitable cap(s) to effectively close the gas inlet(s) when disconnected from the source of supply and not in use shall be attached to the recreational vehicle. Inlets shall be effectively capped when disconnected from the source of supply.

2-4.14.2 The LP-Gas only supply inlet shall be effectively capped to prevent entrance of water and foreign materials when the recreational vehicle is shipped with the LP-Gas containers disconnected from the system.

2-4.15 Prohibiting Use of Gas Piping as Electrical Ground.

Gas piping shall not be used for a grounding electrode.

2-4.16 Gas Pipe Couplings.

Sections of threaded pipe shall be joined by pipe couplings or ground joint unions. Right and left nipples and couplings shall not be used.

2-4.17 Gas Piping Support.

All gas piping shall be supported at intervals of not more than 4 ft (1.2 m), except where adequate support and protection is provided by structural members. All pipe shall be rigidly anchored to a structural member within 6 in. (152.4 mm) of the supply connection(s) by galvanized, painted, or equivalently protected metal straps or hangers. All pipe shall be anchored within 6 in. (152.4 mm) of tubing connections at the end of pipe runs and within 12 in. (304.8 mm) of tubing connection within pipe runs.

2-4.18 Testing for Gas Leakage.

2-4.18.1 Before Appliances Are Connected. Piping systems shall be proven by test to be leak-free by maintaining an air pressure of at least 6 in. mercury (20.7 kPa) or 3 psi (20.7 kPa) for a period of at least ten minutes. Before the test is begun, the temperature of the air and of the piping shall be approximately the same, and a uniform temperature shall be maintained throughout the period. Leaks, if observed, shall be located and corrected. Defective material shall be replaced. Tests shall be conducted by either of the following methods:

(a) The source of the air pressure to the piping system shall be shut off. The pressure in the system shall be measured over a period of ten minutes with a mercury manometer, slope gauge, or equivalent device, calibrated so as to be read in increments of not greater than $^{1}/_{10}$ psi (0.7 kPa). During the ten-minute period a drop in pressure shall not occur.

(b) A bubble-type leak detector shall be installed between the source of air pressure and the piping system. After a ten-minute equalization period, the bubble detector shall not indicate any air flow for a period of one minute. Products that contain ammonia or chlorine shall not be used for testing.

2-4.18.2 After Appliances Are Connected. When appliances are connected to the piping system, the entire piping system shall be pressurized to not less than 10 in. water column (2.5 kPa) nor more than 14 in. water column (3.5 kPa) and the appliance connections tested for leakage with either soapy water or bubble solution. Products containing ammonia or chlorine shall not be used. As an alternative procedure a pressure drop test can be conducted in the following manner:

The entire system shall be pressurized to not less than 10 in. water column (2.5 kPa) nor more than 14 in. water column (3.5 kPa), the appliance shutoff valves closed, and the source of pressure shut off. The temperature of both the air and piping shall be approximately the same, and a uniform temperature shall be maintained throughout the test period. When the test gauge is installed downstream of an appliance regulator, before the test is begun, open one valve and lower the pressure to 9 in. water column (2.24 kPa) ± 0.5 so that the appliance regulator is in an open condition. The pressure in the system shall be measured over a period of three minutes with a manometer or with a pressure-sensing device designed and calibrated to read, record, or indicate a pressure loss due to leakage during the pressure test period. During the three-minute period, a drop in pressure shall not occur.

2-5 Fuel Oil Piping System.

2-5.1 General.

The requirements of this section shall govern the installation of all fuel oil piping attached to any recreational vehicle. None of the requirements listed in this section shall apply to the piping in the appliance(s).

2-5.2 Oil Piping System Materials.

All materials used for the installation, extension, alteration, or repair of any oil piping system shall be new and free from defects or internal obstructions. The system shall be made of materials having a melting point of not less than 1450°F (788°C), except as provided in 2-5.4. They shall be permitted to consist of one or more of the following materials:

(a) Pipe shall be steel or wrought-iron pipe complying with ANSI B36.10M, *Welded and Seamless Wrought Steel Pipe*. Threaded copper or brass pipe in iron pipe sizes shall be permitted to be used;

(b) Fittings for oil piping shall be wrought iron, malleable iron, steel, or brass (containing not more than 75 percent copper);

(c) Copper tubing shall be annealed Type K or L conforming to ASTM B 88, *Standard Specifications for Seamless Copper Water Tube*, or shall comply with ASTM B 280, *Specifications for Seamless Copper Tube for Air Conditioning and Refrigeration Field Service*;

(d) Seamless brass tubing shall have a minimum wall thickness of 0.030 in. (0.762 mm); or

(e) Steel tubing shall have a minimum wall thickness of 0.049 in. (1.24 mm), conforming to ASTM A 539, *Standard Specifications for Electric-Resistance Welded Coiled Steel Tubing for Gas and Fuel Oil Lines*, and shall be externally protected from corrosion.

2-5.3 Size of Oil Piping.

The minimum size of all fuel oil tank piping connecting outside tanks to the appliance shall be not smaller than $^{3}/_{8}$ in. O.D. copper tubing or $^{1}/_{4}$ in. IPS. In those cases where No. 1 fuel is used with a listed automatic pump (fuel lifter), $^{1}/_{4}$ in. O.D. copper tubing shall be permitted to be used if specified by the pump manufacturer.

2-5.4 Joints for Oil Piping.

All pipe joints in the piping system, unless welded or brazed, shall be screw joints that comply with ANSI B1.20.1, *Pipe Threads, General Purpose (Inch)*. The material used for welding or brazing pipe connections shall have a melting temperature in excess of 1000°F (538°C).

2-5.5 General Specifications for Flared Oil Tubing Joints.

Flared oil tubing joints shall be in accordance with the following:

(a) After cutting, tubing ends shall be internally reamed prior to flaring.

(b) Flares shall be square with the axis of the tubing within one-half degree.

(c) Flares shall be free from loose scale, burrs, and cracks. Seating surfaces shall be smooth and free from pit marks.

(*See also 2-4.6.*)

2-5.6 Oil Pipe Joint Compound.

Screw joints shall be made up tight with approved pipe joint compound, or other approved material, that shall be applied to the male threads only.

2-5.7 Couplings for Oil Piping.

Where it is necessary to join sections of screw piping, right and left nipples and couplings shall not be used. Ground joint unions shall be permitted to be installed at appliance inlet connections.

2-5.8 Slope of Oil Piping.

Fuel oil piping installed in conjunction with gravity feed systems to oil heating equipment shall slope in a gradual rise upward from a central location to both the oil tank and the appliance in order to eliminate air locks.

2-5.9 Strap Hangers for Oil Piping.

All oil piping shall be adequately supported by galvanized, painted, or equivalently protected metal straps or hangers at intervals of not more than 4 ft (1.2 m), except where adequate support and protection is provided by structural members. Iron-pipe oil supply connection(s) shall be rigidly anchored to a structural member within 6 in. (152 mm) of the supply connection(s). Iron piping shall be anchored within 6 in. (152 mm) of tubing connections at the end of the pipe runs and within 12 in. (304 mm) of tubing connections within runs.

2-5.10 Testing for Oil System Leakage.

Before setting the system in operation, tank installations and piping shall be checked for oil leaks with fuel oil of the same grade as that which will be burned in the appliance. No other material shall be used for testing fuel oil tanks and piping. Tanks shall be filled to a maximum capacity for the final check for oil leakage.

2-6 Fuel-Burning Appliances.

2-6.1 General.

2-6.1.1 Listing Requirements. Fuel-burning appliances and vents necessary for their installation shall be listed for installation in recreational vehicles.

2-6.1.2 Basic Venting Requirements. Fuel-burning, heat-producing, and refrigeration appliances, except ranges and ovens, shall be of the vented type and vented to the outside.

2-6.1.3 Gas Appliance Fuel Utilization. Gas appliances shall be listed for use with LP-Gas only or for use with both natural gas and LP-Gas (convertible from natural gas to LP-Gas and vice versa).

2-6.1.4 Conversion of Appliances. Fuel-burning appliances shall not be converted from one fuel to another unless converted in accordance with the terms of their listings and the appliance manufacturer’s instructions.

2-6.2 Installation of Fuel-Burning Appliances.

2-6.2.1 General Installation Requirements. The installation of each appliance shall conform to the terms of its listing and the appliance manufacturer’s installation instructions. Floor-mounted fuel-burning appliances shall not be installed on carpeting unless the appliance is listed for such installation. Every appliance shall be secured in place to avoid displacement.

2-6.2.2 Requirement for Direct Vent System Appliances. All fuel-burning appliances, except ranges and ovens, shall be designed and installed to provide for the complete separation of the combustion system from the interior atmosphere of the recreational vehicle. Combustion air inlets and flue gas outlets shall be listed as components of the appliance. The required separation shall be obtained by the installation of direct vent system (sealed combustion system) appliances.

Exception No. 1: A fuel-burning refrigerator shall be permitted to be installed to meet the above requirements using panels supplied by the recreational vehicle manufacturer provided that the refrigerator manufacturer furnishes the necessary vents and grills as specified by the listing requirements and, in addition, the refrigerator is equipped with the necessary means to ensure the integrity of the separation of the combustion system when the refrigerator is removed for field service and reinstalled.

Exception No. 2: A fuel-burning appliance shall not need to be of the direct vent type provided that it conforms to all of the following:

(a) It is a vented appliance.

(b) It incorporates provisions for introduction of combustion air from outside the vehicle.

(c) It incorporates a safety control system that will prevent burner operation under any operating conditions that would allow products of combustion to discharge into the interior of the recreational vehicle.

(d) It incorporates provisions either integral to the appliance design or, by use of a safety control system(s) to protect against ignition of flammable materials that could come into contact with any heat source or part of the appliance.

(e) It is listed for recreational vehicle installation and is installed with the terms of the listing.

2-6.2.3 Exterior Appliances. Fuel-burning appliances installed or intended to be used only outside the RV shall be listed but shall not be required to be of the direct vent, sealed combustion type. The installation shall preclude the possibility of appliance operation or gas flow when the appliance is in its storage (travel) position. The appliance manufacturer shall specify clearance to adjacent surfaces as applicable in both the operational and storage positions.

2-6.2.4 Auxiliary Heating Devices. Primary mover engine auxiliary devices for heating interior living or storage space, or for heating potable water, shall not be required to be listed. Heat exchangers used in the potable water system shall be identified by the device manufacturer as being of a double-wall construction. Exhaust termination of engine block heaters with a gasoline- or diesel-fired source other than the primary mover engine shall comply with 3-4.3.

2-6.2.5 Special Requirement for Forced-Air Heating Appliances. A forced-air heating appliance and its return-air system shall be designed and installed so that negative pressure created by the air-circulating fan cannot affect its, or another appliance’s, combustion air supply or act to mix products of combustion with circulating air.

2-6.3 Venting, Ventilation, and Combustion Air.

2-6.3.1 Installation of Venting and Combustion Air Systems. Venting and combustion air systems shall be installed in accordance with the following:

(a) Components shall be securely assembled and properly aligned using the method shown in the appliance manufacturer’s instructions.

(b) Vent connectors shall be firmly attached to flue collars by sheet metal screws, their equivalent, or as specified in the manufacturer’s installation instructions.

(c) Every joint of a vent, vent connector, exhaust duct, and combustion air intake shall be secure and in alignment.

2-6.3.2 Location of Flue Gas Outlets of Fuel-Burning Heating Appliances. Flue gas outlets from fuel-burning heating appliances shall be not less than 3 ft (0.9 m) from any motor-driven air intake discharging into habitable areas of the recreational vehicle. Flue gas outlets shall not terminate underneath a recreational vehicle.

2-6.3.3 Location of Combustion Air Inlets, Flue Gas Outlets, Fuel-Burning Heating Appliances. Any portion of a combustion air inlet or a flue gas outlet of a fuel-burning heating appliance shall be located at least 3 ft (0.9 m) from any gasoline filler spout on the vehicle if the inlet or outlet is located above or at the same level. If any portion of such inlet or outlet is located below the spout, the distance shall be the sum of the vertical distance below the spout plus 3 ft (0.9 m).

2-6.3.4 Ventilation of Areas Accommodating Fuel-Burning Cooking Appliances. The space where any fuel-burning cooking appliance is located shall be ventilated by a gravity or mechanical vent extending through the roof to the outside. Where a combination gravity/mechanical vent is installed, both operations must comply. A gravity vent shall have a free, clear, openable area not less than 1 $in.^2$ for every 2000 Btuh (11 cm^2/1000 W) rated input of the appliance(s). The location of the vent shall be in the roof within 5 ft (1.5 m) of any point directly above and provide unobstructed flow from the cooking appliances. Vent hood ducts shall be designed so that the duct outlet is located at such a point as to preclude the trapping of products of combustion.

Exception No. 1: Vehicles with fabric exterior walls shall be permitted to utilize an opening through the sidewall not more than 15 in. (381 mm) below the highest point of that roof within 5 ft (1.5 m) of any point directly above the appliance.

Exception No. 2: Hooded gravity vents located directly above the appliance are permitted to exhaust through the sidewall. (See 2-6.7.2.)

Exception No. 3: Mechanical vents (exhaust fans) having a flow rating of 2 cfm (0.19 m^3/m) for every 1000 Btuh (1000 W) rated input of the appliance are permitted to be located on an adjacent wall higher than the appliance within a horizontal distance of not more than 5 ft (1.5 m) from the nearest edge of the appliance.

2-6.4 Marking Appliances (Installation and Operation Features).

2-6.4.1 Clearances, Input Ratings, Lighting, and Shutdown. Information on clearances, input ratings, lighting, and shutdown shall be attached to the appliance with the same permanence as the nameplate and shall be so located that it is easily readable when the appliance is properly installed.

2-6.4.2 Type(s) of Fuel. Each fuel-burning appliance shall bear the appliance manufacturer's permanent marking designating the type(s) of fuel for which it is listed. If listed and installed for use with either LP-Gas or natural gas, the appliance manufacturer's instructions regarding conversion from one fuel to the other shall be attached to the appliance with the same permanence as the nameplate.

2-6.5 Accessibility for Service/Operation.

Every appliance shall be accessible for inspection, service, repair, and replacement without removing permanent construction or other fuel-burning appliances. Sufficient room shall be available to enable the operator to operate the controls, start the appliance, and observe the ignition for those appliances where the appliance manufacturer requires such procedure.

2-6.6 Location of Heat-Producing Appliances.

Heat-producing appliances shall be so located that doors, drapes, or other such material cannot be placed or swung closer to the appliance than the clearances specified on the labeled appliances.

2-6.7 Clearances of Heat-Producing Appliances.

2-6.7.1 Maintaining Listed Clearances. Clearances between heat-producing appliances and adjacent surfaces shall be not less than as specified in the terms of their listing. Clearance spaces shall be framed in or guarded to prevent creation of storage space within the clearance specified. The only exceptions to framing-in or guarding such spaces will be those necessary to allow access to shutoff valves or controls in order to comply with 2-4.9 and 2-6.2.1, in which case the unguarded area must have a warning tag, posted in an easily readable location, as follows:

WARNING

DO NOT STORE COMBUSTIBLE MATERIAL

IN THIS AREA

2-6.7.2 Vertical Clearances of Ranges. Ranges shall have a vertical clearance between the cooking top and combustible material or metal cabinets in accordance with Table 2-6.7.2 or the terms of their listings.

Exception: Range covers.

Table 2-6.7.2 Vertical Clearances to Combustible Material or Metal Cabinets

Type of Protection Provided to Combustible Material or Metal Cabinets above Range	Top Burner Rating	Oven Burner Rating	Vertical Clearance Required above Range Top
1. No protection provided.	Any combination, number, or input.	Any	30 in (762 mm)
2. 1/4-in. (6-mm) thick minimum insulating millboard covered with 28 U.S. gauge sheet metal extending 9 in. (229 mm) beyond the sides of the range and covering the entire bottom of the material to be protected extending over the top of range. In lieu of 28 gauge sheet metal, a hood, 28 U.S. gauge sheet metal, can be used. Hood shall be not less than the width of the range and shall be centered over the range and cover the entire bottom of the material to be protected.	Any combination, number, or input.	Any	24 in. (610 mm)
3. Range hood 28 U.S. gauge, with minimum 2-in. (51-mm) vertical	Not more than 4 top burners — input not to	10,000 Btuh	19 1/2 in. (495 mm)

sides and provided with a bead or flange around top of hood to provide a minimum 1/4-in. (6-mm) dead air space between hood and protected material. Hood shall be not less than the width of the range and shall be	exceed 6000 Btuh (1758 W) each, or not more than 3 top burners — 2 burners input not to exceed 7000 Btuh (2051 W) each and 1 burner input not to exceed 10,000 Btuh (2931 W).	(2931 W)	
installed centered over range and cover the entire bottom of the material to be protected extending over.the	Not more than 4 top burners — input not to exceed 9000 Btuh (2638 W) each.	24,000 Btuh (7034 W)	20 3/4 in. (514 mm)
top of range	2 rear burners — input not to exceed 9000 Btuh (2638 W) each and 2 front burners — input not to exceed 12,000 Btuh (3517 W) each.	22,000 Btuh (6448 W)	23 1/2 in. (597 mm)
4. Same as No. 3, except no dead air space clearance provided.	Not more than 4 burners input not to exceed 9000 Btuh (2638 W) each.	22,000 Btuh (6448 W)	23 in. (584 mm)

2-6.8 Clothes Dryers.

2-6.8.1 Exhaust Duct System. All gas and electric clothes dryers shall be exhausted to the outside by a moisture-lint exhaust duct and termination fitting.

Exception: Listed electric clothes dryers that are not required to be vented to the outside.

2-6.8.2 Where the clothes dryer is supplied by the manufacturer, the exhaust duct and termination fittings shall be provided by the manufacturer in accordance with the following:

(a) A clothes dryer moisture-lint exhaust duct shall not be connected to any other duct, vent, or chimney.

(b) The exhaust duct shall be of sufficient length so as not to terminate beneath the recreation vehicle.

(c) Moisture-lint exhaust ducts shall not be connected with sheet metal screws or other fastening devices that extend into the interior of the duct.

(d) Moisture-lint exhaust duct and termination fittings shall be installed in accordance with the appliance manufacturer's printed instructions.

2-6.8.3 Prevention of Negative Pressure in Recreation Vehicles. Fuel-burning clothes dryers shall receive their combustion air and drying air from outside the vehicle and shall exhaust the combustion products and drying air from inside the vehicle. A warning label with $^{3}/_{8}$ in. (9 mm) high letters shall be posted on or near the dryer in a conspicuous location that shall read:

CAUTION: OPEN A WINDOW OR VENT WHILE OPERATING DRYER. IT IS DANGEROUS TO CREATE A NEGATIVE AIR PRESSURE INSIDE A TRAILER CONTAINING FUEL-BURNING APPLIANCES.

2-6.8.4 Provisions for Future Installation of a Gas Clothes Dryer. A recreation vehicle shall be permitted to be provided with gas piping to facilitate a future gas clothes dryer installation by the owner provided it complies with the following provisions:

(a) Its gas outlet shall be provided with a shutoff valve, the outlet of which is closed by threaded pipe plug or cap;

(b) Its gas outlet shall be permanently labeled to identify it for use only as the supply connection for a gas clothes dryer;

(c) A moisture-lint exhaust duct system shall be roughed in by the manufacturer.

The manufacturer shall provide written instructions to the owner on how to complete the exhaust duct installation in accordance with provisions of 2-6.8.2.

2-6.8.5 Provisions for Future Installation of an Electric Clothes Dryer. When wiring is installed to supply an electric clothes dryer for future installation by the owner, the manufacturer shall install a receptacle for future connection of the dryer and provide written instructions on how to complete the exhaust duct installation in accordance with the provisions of 2-6.8.2.

2-6.8.6 Clothes Dryers Installed in Closets or Alcoves. Each clothes dryer installed in closets or in alcoves shall be listed as suitable for such installation. Closets containing clothes dryers shall have ventilation openings sized in accordance with the appliance manufacturer's installation instructions.

2-7 Circulating Air Systems for Heating (Other than Automotive-type).

2-7.1 Supply System Ducts.

Air supply ducts shall be made of galvanized steel, tin-plated steel, aluminized steel, or aluminum; or made of Class 0 or Class 1 listed air ducts or air connectors as tested in accordance with UL 181, *Standard for Factory-Made Air Ducts and Air Connectors*. A duct system integral with the structure shall be of durable construction that can be demonstrated to be equally resistant to fire and deterioration. Air ducts and plenums constructed of sheet metal shall be in accordance with Table 2-7.1.

Table 2-7.1 Minimum Metal Thickness for Ducts*

	Diameter 14 in. (381 mm) or less	or	Width Over 14 in. (381 mm)
Round Exposed	0.013 in. (0.33 mm)		0.016 in. (0.41 mm)
Enclosed Rectangular or Round	0.013 in. (0.33 mm)		0.016 in. (0.41 mm)
Exposed Rectangular	0.016 in. (0.41 mm)		0.019 in. (0.48 mm)

*When "nominal" thicknesses are specified, 0.003 in. shall be added to these "minimum" metal thicknesses.

2-7.2 Sizing of Supply Ducts.

Ducts shall be designed so that where a labeled forced-air furnace is installed and operated continually at its normal input rating in the recreational vehicle, with all registers in full open position, the static pressure measured in the duct plenum shall not exceed that shown on the label of the appliance. Where an air-cooling coil is installed in the system, the total static pressure of the coil and the system shall not exceed that shown on the label of the appliance. The minimum dimension of any branch duct shall be at least $1^1/_2$ in. (38 mm) and of any main duct, $2^1/_2$ in. (63.5 mm).

2-7.3 Static Pressure.

The internal static pressure of the furnace air delivery system shall comply with the furnace manufacturer's instructions.

2-7.4 Return Air System Air Openings.

Provisions shall be made to permit the return of circulating air from all rooms and living spaces to the circulating air supply inlet of the furnace.

Exception: Toilet rooms shall not be required to have return air openings.

2-7.5 Return Air Duct Materials.

Return air ducts, if used, shall be in accordance with the following:

(a) Portions of return air ducts directly above the heating surfaces, or closer than 2 ft (0.6 m) from the outer jacket or casing of the furnace, shall be constructed of metal in accordance with 2-7.1.

(b) Return air ducts, except as required in (a) above, shall be constructed of 1-in. (25-mm) nominal wood boards (flame spread classification of not more than 200) or other suitable material no more combustible than 1-in. (25-mm) board. The interior of such combustible ducts (ducts of material other than as specified in 2-7.1) shall be lined with noncombustible material at points susceptible to damage from incandescent particles dropped through the register or from the furnace, such as directly under floor registers and bottoms of vertical ducts or directly under furnaces having bottom return.

2-7.6 Sizing of Return Air Ducts.

The cross-sectional area of the return air duct shall not be less than 2 in.^{2} for each 1000 Btuh (44 cm^2/1000 W) input rating of the appliance. A complete ducted heating system need not comply with this return air duct sizing requirement if the numerical total of the static pressure at the inlet and the outlet of the appliance is equal to or less than that shown on the label of the appliance. For example: Supply Duct Static Pressure + 0.10 in. water column and Return Air Duct Static pressure - 0.04 in. water column. Numerical Total is 0.14 in. water column static pressure. Dampers shall not be placed in any return air duct, except that a diverting damper shall be permitted to be placed in a combination fresh air intake and return air duct so arranged that the required cross-sectional area will not be reduced at all possible positions of the damper.

2-7.7 Return Air Duct Permanent Unclosable Openings.

Living areas not served by return air ducts and closed off from the return opening of the furnace by doors, sliding partitions, or other means shall be provided with permanent unclosable openings in the doors or separating partitions to allow circulated air to return to the furnace. Such openings shall be permitted to be grilled or louvered. The net free area of each opening shall be not less than 1 in.^{2} (6.5 cm^2) for every 5 ft^2 (0.46 m^2) of total living area closed off from the furnace by the door or partition serviced by that opening. Undercutting doors connecting the closed-off area shall be permitted to be used as a means of providing return air area. However, in the event that doors are undercut, not more than one-half of the free air area provided shall be considered return air area.

2-7.8 Air Duct Joints and Seams.

Joints and seams of ducts shall be securely fastened and made substantially airtight. Slip joints shall have a lap of at least 1 in. (25 mm) and shall be individually fastened. Tape or caulking compound shall be permitted to be used for sealing mechanically secure joints. Where used, tape or caulking compound shall not be subject to deterioration under long exposures to temperatures up to 200°F (93.4°C) and to conditions of high humidity, excessive moisture, or mildew.

2-7.9 Air Duct Supports.

Ducts shall be securely supported.

2-7.10 Air Duct Registers or Grills.

Fittings connecting the registers or grills to the duct system shall be constructed of metal or material that complies with the requirements for Class 0, or Class 1 air ducts under UL 181, *Standard for Factory-Made Air Ducts and Air Connectors*. Registers or grills shall be constructed of metal or conform with the following:

(a) Registers or grills shall be made of a material classified 94 V-0 or 94 V-1 when tested as described in UL 94, *Standard for Tests for Flammability of Plastic Materials for Parts in Devices and Appliances*.

(b) Floor registers or grills shall resist without structural failure a 200-lb (90.7-kg) concentrated load on a 2-in. (51-mm) diameter disc applied to the most critical area of the exposed face of the register or grill. For this test the register or grill is to be at a temperature of not less than 165°F (74°C) and is to be supported in accordance with the manufacturer's instructions.

Exception: This section does not apply to ducted rooftop air conditioning systems with heat strips or heat pumps where the system does not exceed 175°F when tested in accordance with UL 484, Standard for Safety Room Air Conditioners.

2-8 Air Conditioning (Other than Automotive-type).

2-8.1 General Requirement — Air Conditioning Appliances.

Every air conditioning appliance or combination air conditioning and heating appliance used in a recreational vehicle shall be listed or certified for the application for which the air conditioning appliance is intended and shall be installed in accordance with the terms of its listing.

2-8.2 Air Conditioning Installation and Instructions.

2-8.2.1 Installation of Air Conditioning Appliances. The installation of each appliance shall conform to the terms of its listing and the manufacturer's installation instructions. Appliances shall be secured in place to avoid displacement and movement from vibration and road shock.

2-8.2.2 Rating Plates for Air Conditioning Appliances. The air conditioner rating plate shall be located so that it is easily readable when the appliance is installed.

2-8.2.3 Fuel-Burning Air Conditioners. Each fuel-burning air conditioner shall comply with Section 2-6.

2-8.2.4 Accessibility of Air Conditioners. Each air conditioner shall be accessible for inspection, service, repair, and replacement without removing permanent construction.

2-9 Consumer Information.

2-9.1 Required Information.

2-9.1.1 Instructions for Appliances. Operating instructions shall be provided for each appliance, including air conditioning appliances (other than automotive-type).

2-9.1.2 Owner's Manual. Each recreational vehicle shall be provided with an owner's manual that shall contain the following information as a minimum:

(a) WARNING: LP-Gas containers shall not be placed or stored inside the vehicle. LP-Gas containers are equipped with safety devices that relieve excessive pressure by discharging gas to the atmosphere.

(b) The following warning label has been located in the cooking area to remind the user to provide an adequate supply of fresh air for combustion:

WARNING: IT IS NOT SAFE TO USE COOKING
APPLIANCES FOR COMFORT HEATING

Cooking appliances need fresh air for safe operation. Before operation:

1. Open overhead vent or turn on exhaust fan, and
2. Open window.

Unlike homes, the amount of oxygen supply is limited due to the size of the recreational vehicle, and proper ventilation when using the cooking appliance(s) will avoid dangers of asphyxiation. It is especially important that cooking appliances not be used for comfort heating as the danger of asphyxiation is greater when the appliance is used for long periods of time.

(c) A warning label has been located near the LP-Gas container. This label reads:

DO NOT FILL CONTAINER(S) TO MORE THAN 80 PERCENT OF CAPACITY

Overfilling the LP-Gas container can result in uncontrolled gas flow, which can cause fire or explosion. A properly filled container will contain approximately 80 percent of its volume as liquid LP-Gas.

(d) A warning that portable fuel-burning equipment, including wood and charcoal grills and stoves, shall not be used inside the recreational vehicle. The use of this equipment inside the recreational vehicle can cause fires or asphyxiation.

(e) A warning that states not to bring or store LP-Gas containers, gasoline, or other flammable liquids inside the vehicle because a fire or explosion can result.

(f) The following label has been placed in the vehicle near the range area:

IF YOU SMELL GAS:

1. Extinguish any open flames, pilot lights, and all smoking materials.
2. Do not touch electrical switches.
3. Shut off the gas supply at the tank valve(s) or gas supply connection.
4. Open doors and other ventilating openings.
5. Leave the area until odor clears.
6. Have the gas system checked and leakage source corrected before using again.

(g) LP-Gas regulators must always be installed with the diaphragm vent facing downward. Regulators that are not in compartments have been equipped with a protective cover. Make sure that the regulator vent faces downward and that the cover is kept in place to minimize vent blockage that could result in excessive gas pressure causing fire or explosion.

2-9.2 Required Markings.

2-9.2.1 Identification of Gas Supply Connections. Each recreational vehicle shall have permanently affixed to the exterior skin at or near each gas supply connection, or at the end of the pipe, a plate complying with the requirements for exterior labels (*see 1-4*) 3 in. × $1^3/_4$ in. (76 mm × 44 mm) minimum size that reads (as appropriate) either:

(a) THIS GAS PIPING SYSTEM IS DESIGNED FOR USE OF LIQUEFIED PETROLEUM GAS ONLY. DO NOT CONNECT NATURAL GAS TO THIS SYSTEM. Securely cap inlet(s) when not connected for use. After turning on gas, except after normal container replacement, test gas piping and connections to appliances for leakage with soapy water or bubble solution. Do not use products that contain ammonia or chlorine. Or,

(b) THIS GAS PIPING SYSTEM IS DESIGNED FOR USE OF EITHER LP-GAS OR NATURAL GAS. BEFORE TURNING ON GAS BE CERTAIN APPLIANCES ARE DESIGNED AND ARRANGED FOR THE GAS CONNECTED. (SEE EACH APPLIANCE INSTRUCTION PLATE.) Securely cap this inlet when not connected for use. After turning on gas, except after normal container replacement, test gas piping and connections to appliances for leakage with soapy water or bubble solution. Do not use products that contain ammonia or chlorine.

2-9.2.2 Warning Relative to Refueling.

(a) Each vehicle shall have a permanent label adjacent to the LP-Gas container that reads:

DO NOT FILL LP-GAS CONTAINER(S) TO MORE THAN 80 PERCENT OF CAPACITY

(b) Each motor home or truck camper having exterior combustion air inlet(s) at a level below the roof shall have a permanent label that reads:

WARNING: ALL PILOT LIGHTS, APPLIANCES, AND THEIR IGNITORS (SEE OPERATING INSTRUCTIONS) SHALL BE TURNED OFF DURING REFUELING OF MOTOR FUEL TANKS AND/OR LP-GAS CONTAINERS

On truck campers this label shall be placed near the front on both the left and right exterior walls. On motor homes and chassis-mounted truck campers, this label shall be placed by the gasoline filler spout and the LP-Gas container.

NOTE: The above labels, where required near the LP-Gas containers, shall be permitted to be incorporated in the plates required in 2-9.2.1.

2-9.2.3 Warning if Gas Odor Is Detected. Where LP-Gas fuel-burning equipment is installed by the recreational vehicle manufacturer, a permanent label with $^3/_8$-in. (9-mm) high title letters and $^1/_8$-in. (3-mm) high text letters shall be affixed in a noticeable location near the range. This label shall be permitted to be affixed to the back of a cabinet door providing the cabinet door will be frequently used.

IF YOU SMELL GAS:

1. Extinguish any open flames, pilot lights, and all smoking materials.
2. Do not touch electrical switches.
3. Shut off the gas supply at the tank valve(s) or gas supply connection.
4. Open doors and other ventilating openings.
5. Leave the area until odor clears.
6. Have the gas system checked and leakage source corrected before using again.

2-9.2.4 Warning Label for Cooking Appliances. A permanent warning label with the word "WARNING" with $^3/_8$-in. (9-mm) high letters and body text with $^1/_8$-in. (3-mm) high letters shall be affixed in a conspicuous manner adjacent to fuel-burning ranges and shall read:

WARNING: IT IS NOT SAFE TO USE COOKING APPLIANCES FOR COMFORT HEATING

Cooking appliances need fresh air for safe operation. Before operation:

1. Open overhead vent or turn on exhaust fan, and
2. Open window.

2-10 Gasoline or Diesel Fuel Systems for Engine Generator Sets for Travel Trailers and Fifth Wheels.

2-10.1 General.

The requirements of this section shall apply to the installation of gasoline or diesel fuel systems for travel trailers and fifth wheels intended for use with engine generator sets.

2-10.1.1 The entire fuel system shall be liquidtight and vaportight from the interior of the vehicle.

2-10.1.2 Valves, filters, strainers, and similar components shall be accessible for maintenance.

2-10.1.3 Auxiliary outlets for drawing fuel from the system other than tank drain plugs shall not be permitted.

2-10.2 Generator Ready.

2-10.2.1 When an electrical generator is not installed at the recreational vehicle factory, all fuel lines between the tank and the generator compartment shall be plugged.

2-10.2.2 The following label shall be located near the fuel filler cap:

CAUTION: DO NOT PUT FUEL IN TANK UNLESS GENERATOR IS INSTALLED AND FUEL LINES ARE CONNECTED. CHECK ALL CONNECTIONS FOR LEAKAGE.

2-10.3 Tank Installation.

2-10.3.1 Location. The tank shall be located under the floor, in a compartment, on a trailer A frame, or forward of the front bulkhead below the overhang of a fifth wheel trailer. Clearances shall be as specified below. All measurements shall be determined from the bottom of the tank, or from the lowest fitting, support, or attachment on the tank or tank housing, whichever is lower, while the vehicle is level and at dry weight.

(a) *Rear clearance line.* Above a plane tangent to a point that is 8 in. (203 mm) above the ground on the vertical centerline of the wheel spindle and the lowest point on the intersection of the rear wall and floor lines (skid bars are excluded).

(b) *Front clearance line.* Above a plane tangent to the point that is 8 in. (203 mm) above the ground on the vertical centerline of the wheel spindle and the lowest point of the frame's front cross member. It is not the intent to prohibit the fuel tank from being located in the A frame area providing neither the tank nor connections extend below the bottom of the trailer frame.

2-10.3.2 The tank shall be permitted to be located in a compartment provided:

(a) A compartment containing a tank with filler opening or vent within the compartment shall have no floor.

(b) A compartment containing a tank that is filled and vented to the exterior shall be permitted to have a floor provided that the compartment side walls and floor are resistant and nonabsorbent to fuel, that the floor has a minimum $^1/_2$-in. (12.7-mm) diameter drainage hole at each potential low point, and that the joints between compartment side walls and floor are sealed to prevent fuel entry.

(c) The fuel tank compartment shall be vaportight to the vehicle interior and sealed so that vapors cannot travel through concealed spaces between the exterior-interior surfaces of the recreational vehicle. Sealing compounds used to seal the compartment shall be fuel resistant.

(d) The fuel tank compartment shall not contain flame- or spark-producing equipment.

2-10.3.3 Securing of Fuel Tanks. The tank shall be secured by fastenings that hold it in place when a force equal to 8 times the tank's filled weight is applied through the tank in any direction.

2-10.4 Fill System.

2-10.4.1 The filler subsystem shall run as directly as possible from the filler cap to the tank. The filler cap end shall be completely above the top of the tank.

2-10.4.2 The area surrounding fuel filler pipes and vents shall be sealed so that vapors cannot travel through concealed spaces between the exterior-interior surfaces of the recreational vehicle. The sidewall surface below the filler cap and extending at least 12 in. (304.8 mm) to each side of the cap's vertical centerline shall be constructed of fuel-resistant nonabsorbent materials. Sealing compounds used around the filler pipe and in this area shall be fuel resistant.

2-10.4.3 A marking indicating the type of fuel to be used shall be provided on or near the filler cap.

2-10.5 Fuel Distribution System.

2-10.5.1 Tubes shall be constructed of steel or material suitable for use with fuel.

2-10.5.2 Hoses shall conform to SAE J30, *Fuel and Oil Hoses, Standard*, except that hose with a wire-inserted rubber tube and cover (SAE 30R5) or similar hose containing wire shall not be used.

2-10.5.3 Hose to tube joints shall remain leak-free when subjected to a 20-lb (9.0-kg) axial pull test applied for one minute.

2-10.5.4 The distribution system shall be supported to minimize chafing and to maintain at least a 6-in. (152-mm) clearance from any unshielded exhaust system component.

2-10.5.5 The fuel system shall not be in contact with electrical wiring except as required for component operation.

2-10.5.6 The fuel system shall be designed so that leakage from tanks or joints will not contact electrical or exhaust system components. (Drain troughs shall be permitted to be used as required.)

2-11 LP-Gas Engine Fuel Installations.

2-11.1

Dual utilization LP-Gas systems supplying both vapor and liquid withdrawal shall comply with Chapter 8, Section 8-2 of NFPA 58, *Standard for the Storage and Handling of Liquefied Petroleum Gases*, except as provided for in 2-11.2.

2-11.2

Permanently mounted ASME containers shall be mounted in accordance with 2-2.3(b)(3) and secured in accordance with 2-2.4.

Chapter 3 Fire and Life Safety Provisions

3-1 Interior Finish and Textile or Film Materials.

3-1.1 Interior Finish Flame Spread Limitation.

Interior finish (*as defined in Section 1-3*) of walls, partitions, ceilings, exterior passage doors, cabinets, habitable areas, hallways, and bath or toilet rooms, including shower/tub walls, of recreational vehicles shall be of materials whose flame spread classification does not exceed 200 when tested in accordance with NFPA 255, *Standard Method of Test of Surface Burning Characteristics of Building Materials*.

An alternate method of testing for cabinet door and drawer faces, exposed cabinet bottoms and end panels, and tub/shower walls shall be permitted to use ASTM E 162, *Test for Surface Flammability of Materials Using a Radiant Heat Energy Source*, to establish the flame spread rating not to exceed 200.

Exception: These flame spread limitations do not apply to moldings; trim; furnishings; windows, *door, or skylight frames and casings; interior passage doors; countertops; cabinet rails, stiles, mullions, toe kicks, and padded cabinet ends.*

3-1.2 Combustibility of Textile or Film Materials.

Where the walls, partitions, or ceilings consist of textile or film materials, such as tent fabric, insect screening, flexible plastic weather protection, etc., they shall conform to the requirements of paragraphs S4.3 and S5 of *Federal Motor Vehicle Safety Standard No. 302*, "Flammability of Interior Materials" (*Code of Federal Regulations*, Title 49, Part 571.302).

3-1.3 Use of Cellular Foam or Foamed Plastic Materials.

Cellular foam or foamed plastic materials shall not be used for interior finish (*as defined in Section 1-3*) in recreational vehicles.

Exception No. 1: Cellular or foamed plastic materials shall be permitted on the basis of fire tests that substantiate on a reasonable basis their combustibility characteristics, for the use intended, in actual fire conditions.

Exception No. 2: Incidental use of such materials for molding, trim, splash panels, and on doors shall be permitted.

3-1.4 Mirrors.

All interior mirrors with an exposed area exceeding 431 in.^{2} (278 064 mm^2) shall comply with ANSI Z97.1, *Safety Glazing Materials Used in Buildings — Safety Performance Specifications and Methods of Test*, or equal requirements and shall be so identified by the manufacturer of the mirror.

3-2 Recreational Vehicle Exit Facilities.

3-2.1* Minimum Exit Facilities.

Recreational vehicles shall have a minimum of two exits located remote from each other and so arranged as to provide a means of unobstructed travel to the outside of the vehicle. Each bedroom or area designed for sleeping shall have at least two unobstructed paths to exit. The path to exit must not require passing any designated exit to gain use of another designated exit except where any part of a bed in its normal sleeping configuration is within 24 in. (610 mm) of the plane of the nearest designated exit as projected across the vehicle. (*See Appendix A, Figure A-3-2.1.*)

3-2.2 Alternate Means in Motor Homes and Truck Campers.

The alternate exits in motor homes and truck campers shall be located on a wall other than that wall where the main vehicle exit door is located, or shall be located in the roof. Use of the driver's door as an alternate egress is permitted provided that the driver's seat locks only in the forward position and arm rests, if any, are retractable and nonlockable when in the arm rest position. The distance between the upright portion of the seat in its extreme forward position and the nearest point of the steering wheel shall be not less than 12 in. (305 mm).

3-2.3 Access to Alternate Exits.

The path leading to an alternate exit, other than that stated in 3-2.2, shall be not less than 13 in. (330 m) wide at the narrowest point and as a minimum shall extend vertically from the supporting surface below the alternate exit to the top of the alternate exit. The supporting surface shall be not more than 3 ft (0.9 m) below the bottom of the alternate exit and shall be capable of supporting a weight of 300 lb (136 kg). Recreational vehicles that contain a designated roof alternate exit shall be provided with a ladder or equivalent device for descending from the roof.

3-2.4 Operation of Exits.

The latch mechanism of any required exit facility shall be operable by hand and shall not require the use of a key or tool for operation from the inside. No more than 20 lb of force (89 N) shall be required to open a required exit.

3-2.5* Size of Alternate Exits.

The alternate exit, if not an exterior passage door, shall provide an opening of sufficient size to permit unobstructed passage, keeping a major axis parallel to the plane of the opening and horizontal at all times, of an ellipsoid generated by rotating about its minor axis an ellipse having a major axis of 24 in. (610 mm) and a minor axis of 17 in. (432 mm). (*See Appendix A, Figure A-3-2.5.*) An exterior passage door if used for an alternate exit shall provide an unobstructed opening with a minimum horizontal dimension of 18 in. (457 mm) and a minimum vertical dimension of 48 in. (1.2 m).

3-2.6 Marking of Exits.

Alternate exits other than exterior passage doors shall be identified by a waterproof label with the word "EXIT" in 1-in. (25.4-mm) minimum red letters on a contrasting background. The label shall be placed on the interior wall surface above or below the exit or on the interior ceiling surface, within 8 in. (203 mm) of the opening in an unobscured visible location or shall be installed on the interior of the exit frame or the moveable portion of the exit approximately midway between the sides.

3-2.7 Identification of Exit Handles.

Handles that must be operated to open alternate exits shall be colored red.

Exception: Exterior and interior passage door handles shall not need to be colored.

3-3 Fire Detection Equipment.

3-3.1 Smoke Detector.

At least one integral battery-operated smoke detector shall be installed in each travel trailer or motor home that has a sleeping area separated from the living and cooking area by a door.

Exception: A travel trailer that has only interior lighting capable of being powered only by a 120-volt or 120-volt/240-volt external power supply shall be permitted to be equipped with a 120-volt operated smoke detector that shall be on a branch-circuit supplying lighting and receptacle outlets that shall not have ground-fault protection.

3-3.2* Smoke Detector Listing Requirement.

The smoke detector shall be listed and marked on the device as being suitable for installation in recreational vehicles under the requirements of UL 217, *Standard for Single and Multiple Station Smoke Detectors*. (*Also see Appendix A, A-3-3.2.*)

3-3.3 Installation of Smoke Detector.

The required smoke detector shall be installed in accordance with its listing, but not within the separate sleeping areas, a minimum of 6 in. (152 mm) from all exterior walls measured edge to edge and away from the direct flow of air from heat and air conditioning outlets.

3-3.4 Operational Check Warning Label.

A permanent label shall be installed in a visible location on or within 24 in. (610 mm) of the smoke detector with the following text in contrasting letters at least $^{1}/_{8}$ in. (3.2 mm) high:

WARNING TEST SMOKE DETECTOR OPERATION AFTER VEHICLE HAS BEEN IN STORAGE, BEFORE EACH TRIP, AND AT LEAST ONCE PER WEEK DURING USE

3-4 Other Considerations.

3-4.1 Provisions for Portable Fire Extinguishers.

Each motor home shall be equipped with a listed portable fire extinguisher with a minimum rating of 10B:C. Each recreational vehicle equipped with fuel-burning equipment (other than the prime mover engine) or 120/240 volt electrical system shall be provided with a listed portable fire extinguisher with a minimum rating of 5B:C as defined in NFPA 10, *Standard for Portable Fire Extinguishers*.

The fire extinguisher shall be installed in accordance with its listing and Section 1-6 of NFPA 10, *Standard for Portable Fire Extinguishers*, and shall be located within the recreational vehicle interior as near as practical to the primary means of egress.

3-4.2 Fuel Spout Installation.

The area surrounding liquid fuel filler pipes and vent tubing shall be sealed so that fuel vapors cannot travel into concealed spaces between exterior and interior surfaces of the recreational vehicle nor to the interior of the vehicle (*see also Chapter 2*). Materials and sealants used to seal the fill pipe and vent tubing location shall be nonabsorbent and resistant to intermittent contact (splashing) with fuel.

3-4.3 Internal Combustion Engine Exhausts.

Exhausts from internal combustion engines shall not terminate under the vehicle. Exhausts shall extend beyond the periphery of the vehicle so that exhaust gases discharge away from the vehicle. Internal combustion engine exhaust components installed by the RV manufacturer shall not extend or protrude in a manner where they could be unduly subject to road damage. Internal combustion engine exhaust shall not terminate so that a communicable air passage exists into the living area within an area defined as a distance of 6.0 in. (152 mm) as measured from the tailpipe termination perimeter as projected onto the vehicle side. Regardless of location of vehicle exhaust, vents or windows that can be opened shall not be installed in the rear wall of motor home and truck campers.

Exception No. 1: Normally unopenable alternate egress windows shall be permitted to be installed in rear walls.

Exception No. 2: Rear entry doors with fixed windows shall be permitted to be installed in truck campers.

Exception No. 3: Rear entry doors with fixed windows shall be permitted to be installed in motor homes provided that no combustion engine exhausts discharge from the rear of the vehicle.

3-4.4 Floor Penetrations.

No uncovered hole(s) shall be permitted in or through the floor of a recreational vehicle that is equipped with, or designed for future installation of, an internal combustion engine(s). Holes or other penetrations provided for piping, wiring, or other similar components for systems addressed by this standard shall be sealed.

3-4.5 Installation of Internal Combustion Engine Generators.

Internal combustion engine-driven generator units (subject to the provisions of this standard) shall be secured in place to avoid displacement in accordance with manufacturer's instructions and shall be installed in a compartment that is vaportight to the interior of the vehicle.

Where generator compartments are used to isolate the generator from the vehicle's interior, generator compartments shall be lined with galvanized steel not less than 26 MSG thick. Seams and joints shall be lapped, mechanically secured, and made vaportight to the interior of the vehicle. Alternate materials and methods of construction shall be permitted to be used if they provide equivalent quality, strength, effectiveness, fire resistance, durability, and safety. Liquid fuel lines and exhaust systems shall not penetrate into the living area. Holes into the living area shall be sealed vaportight.

3-4.6 Carbon Monoxide (CO) Detectors.

All RVs equipped with an internal combustion engine or designed with features to accommodate future installation of an internal combustion engine and all truck campers shall be equipped with a CO detector listed as suitable for use in recreational vehicles under the requirements of UL 2034, *Standard for Safety Single and Multiple Station Carbon Monoxide Detectors*, and installed according to the terms of its listing.

3-4.7 LP-Gas Detectors.

All recreational vehicles equipped with an LP-Gas appliance and electrical system shall be equipped with an LP-Gas detector listed as suitable for use in recreational vehicles under the requirements of UL 1484, *Standard for Safety Residential Gas Detectors*, and installed according to the terms of its listing.

3-4.8 Special Transportation Provisions.

All recreational vehicles providing any entrance door greater than 36 in. (914 mm) in width, and an access ramp for that door, or that are promoted as providing or provide the ability for transporting or storing internal combustion engine vehicles shall provide the following:

(a) A minimum of one opening or window on each side of the vehicle having a minimum of 200 $in.^2$ (129 032 mm^2) of free openable area. The top of the opening or window shall not be more than 18 in. above the vehicle's interior floor level.

(b) Seamless floor coverings nonabsorbent to fuel extending along the entire floorline of the transportation area and sealed to the wall with sealant that is resistant to intermittent contact (splashing) with fuel.

(c) Electrical equipment and lighting installed in accordance with Sections 511-6(d) and 511-7(b) of NFPA 70, *National Electrical Code*.

(d) A listed portable fire extinguisher with a minimum rating of 10B:C, as defined in NFPA 10, *Standard for Portable Fire Extinguishers*.

(e) LP-Gas ranges and ovens, if provided, shall not contain pilot lights or shall be equipped with a pilot light shutoff.

(f) A warning label placed inside of the RV adjacent to each entry and visible to anyone entering the RV. This label(s) shall be printed with red letters on a white background with the word "WARNING" a minimum of $^3/_4$ in. (19 mm) high, text that shall be a minimum of $^1/_4$ in. (6 mm) high and shall read:

WARNING

Any motorized vehicle or any motorized equipment powered with flammable liquid can cause fire or explosion or asphyxiation if stored or transported within the recreational vehicle. To reduce the risk of fire, explosion, or asphyxiation:

1. Do not allow passengers to ride inside internal combustion engine vehicle storage area while vehicles are present.

2. Run fuel out of engine after shutting off fuel at the tank.

3. Do not store or transport supplementary motor fuel within this vehicle.

4. Ventilate the interior of the vehicle to reduce the risk of fire, explosion, or asphyxiation.

5. Do not operate gas appliances, pilot lights, or electrical equipment when motorized vehicles or motorized equipment are inside vehicle.

(g) A statement in the owner's manual warning of the hazards of transporting, storing, or cohabiting with internal combustion engines inside the vehicle.

(h) A label affixed to the interior of the vehicle and a statement in the owner's manual explaining the proper weight distribution for the transportation of internal combustion engine vehicles.

Exception No. 1: Recreational vehicles having vaportight separation between the special transportation area and the living space are exempt from the requirements of 3-4.8(e) and (f).

Exception No. 2: Recreational vehicles designed and promoted for the physically impaired are not required to comply with the requirements of 3-4.8.

Exception No. 3: Portions of recreational vehicles designed to transport animals are not required to comply with 3-4.8.

Chapter 4 Plumbing Systems

Requirements for plumbing are developed by the ANSI A119 Committee of which the Recreational Vehicle Industry Association is Secretariat. Those requirements and the fire safety requirements in this standard are published and distributed under one cover as ANSI A119.2/ NFPA 501C.

Chapter 5 Referenced Publications

5-1

The following documents or portions thereof are referenced within this standard and shall be

considered part of the requirements of this document. The edition indicated for each reference is the current edition as of the date of the NFPA issuance of this document.

5-1.1 NFPA Publications.

National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.

NFPA 10, *Standard for Portable Fire Extinguishers*, 1994 edition.

NFPA 58, *Standard for the Storage and Handling of Liquefied Petroleum Gases*, 1995 edition.

NFPA 70, *National Electrical Code*, 1996 edition.

NFPA 97, *Standard Glossary of Terms Relating to Chimneys, Vents, and Heat-Producing Appliances*, 1992 edition.

NFPA 255, *Standard Method of Test of Surface Burning Characteristics of Building Materials*, 1996 edition.

5-1.2 Other Publications.

5-1.2.1 ANSI Publications. American National Standards Institute, 1430 Broadway, New York, NY 10018.

ANSI A119.5, *Standard for Park Trailers*, 1993.

ANSI B1.20.1, *Pipe Threads, General Purpose (Inch)*, 1983.

ANSI B36.10M, *Welded and Seamless Wrought Steel Pipe*, 1985.

ANSI Z21.40.1, *Gas-Fired Absorption Summer Air-Conditioning Appliances; Addenda Z21.40.1A-198*, 1981.

ANSI Z97.1, *Safety Glazing Materials Used in Buildings — Safety Performance Specifications and Methods of Test*, 1984.

5-1.2.2 ASME Publication. American Society of Mechanical Engineers, 345 East 47th Street, New York, NY 10017.

ASME Boiler and Pressure Vessel Code, Section VIII, Division I, Rules for Construction of Unfired Pressure Vessels.

5-1.2.3 ARI Publication. Air-Conditioning and Refrigeration Institute, 1501 Wilson Blvd., Suite 600, Arlington, VA 22209.

ARI Standard 250, *Electrically Driven Mechanical Compression-type Air Conditioners*, 1974.

5-1.2.4 ASTM Publications. American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103.

ASTM B 88, *Standard Specifications for Seamless Copper Water Tube*, Rev A-93.

ASTM B 280, *Specifications for Seamless Copper Tube for Air Conditioning and Refrigeration Field Service*, Rev A-93.

ASTM E 380, *Standard Practice for Use of the International System of Units (SI) (the Modernized Metric System)*, 1993.

ASTM A 539, *Standard Specifications for Electric-Resistance Welded Coiled Steel Tubing for Gas and Fuel Oil Lines*, Rev A-90.

ASTM E 162, *Test for Surface Flammability of Materials Using a Radiant Heat Energy*

Source, 1994.

5-1.2.5 UL Publications. Underwriters Laboratories Inc., 333 Pfingsten Road, Northbrook, IL 60062.

UL 94, *Standard for Tests for Flammability of Plastic Materials for Parts in Devices and Appliances*, 1991.

UL 181, *Standard for Factory-Made Air Ducts and Air Connectors*, 1994.

UL 217, *Standard for Single and Multiple Station Smoke Detectors*, 1985.

UL 484, *Standard for Safety Room Air Conditioners*, 1993.

UL 569, *Standard for Safety Pigtails and Flexible Hose Connectors for LP-Gas*, 1995.

UL 1484, *Standard for Safety Residential Gas Detectors*, 1994.

UL 2034, *Standard for Safety Single and Multiple Station Carbon Monoxide Detectors*, 1992.

5-1.2.6 SAE Publications. Society of Automotive Engineers, Inc., 400 Commonwealth Drive, Warrendale, PA 15096.

SAE J533, *Flares for Tubing, Standard*, 1992.

SAE J30, *Fuel and Oil Hoses*, Standard, 1993.

5-1.2.7 Government Publications. U.S. Government Printing Office, Washington, DC 20234.

U.S. Department of Transportation, *Specifications for LP-Gas Containers*.

Federal Motor Vehicle Safety Standard No. 302, "Flammability of Interior Materials" (Code of Federal Regulations, Title 49, Part 571.302, paragraphs S4.3 and S5).

Appendix A Explanatory Material

This Appendix is not a part of the requirements of this NFPA document but is included for informational purposes only.

A-1-3

Other definitions relating to heat-producing appliances are contained in NFPA 97, *Standard Glossary of Terms Relating to Chimneys, Vents, and Heat-Producing Appliances*.

A-1-3 Approved.

The National Fire Protection Association does not approve, inspect, or certify any installations, procedures, equipment, or materials; nor does it approve or evaluate testing laboratories. In determining the acceptability of installations, procedures, equipment, or materials, the authority having jurisdiction may base acceptance on compliance with NFPA or other appropriate standards. In the absence of such standards, said authority may require evidence of proper installation, procedure, or use. The authority having jurisdiction may also refer to the listings or labeling practices of an organization concerned with product evaluations that is in a position to determine compliance with appropriate standards for the current production of listed items.

A-1-3 Authority Having Jurisdiction.

The phrase "authority having jurisdiction" is used in NFPA documents in a broad manner, since jurisdictions and approval agencies vary, as do their responsibilities. Where public safety isprimary, the authority having jurisdiction may be a federal, state, local, or other regional department or individual such as a fire chief; fire marshal; chief of a fire prevention bureau, labor department, or health department; building official; electrical inspector; or others having statutory authority. For insurance purposes, an insurance inspection department, rating bureau, or other insurance company representative may be the authority having jurisdiction. In many circumstances, the property owner or his or her designated agent assumes the role of the authority having jurisdiction; at government installations, the commanding officer or departmental official may be the authority having jurisdiction.

A-1-3 Gross Trailer Area.

In calculating the square footage, measurements should be taken on the exterior. Square footage includes all siding, corner trims, moldings, storage spaces, areas enclosed by windows but not the roof overhangs (Ref. HUD Interpretive Bulletin A-1-88).

Expandable room sections, regardless of height, should be included. Storage lofts contained within the basic unit should have ceiling heights less than 5 ft (1.5 m) and would not constitute additional square footage.

A-1-3 Listed.

The means for identifying listed equipment may vary for each organization concerned with product evaluation, some of which do not recognize equipment as listed unless it is also labeled. The authority having jurisdiction should utilize the system employed by the listing organization to identify a listed product.

A-1-6

SI stands for the International System of Units, which is officially abbreviated SI in all languages. For full explanation, see ASTM E 380, *Standard Practice for Use of the International System of Units (SI) (the Modernized Metric System).*

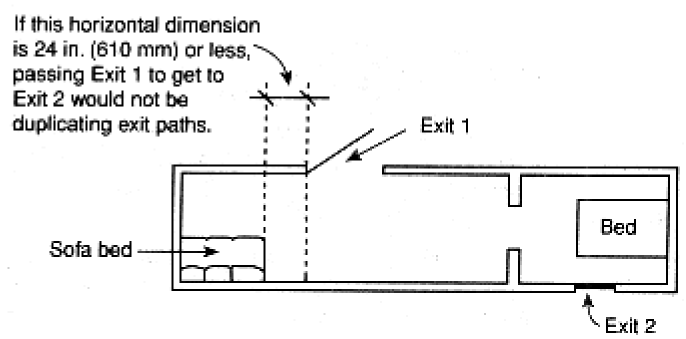


Figure A-3-2.1 Bed within 24 in. (610 mm) of the plane of the nearest designated exit.

A-3-2.5

This diagram is useful in explaining the method of measuring the alternate exit in 3-2.5.

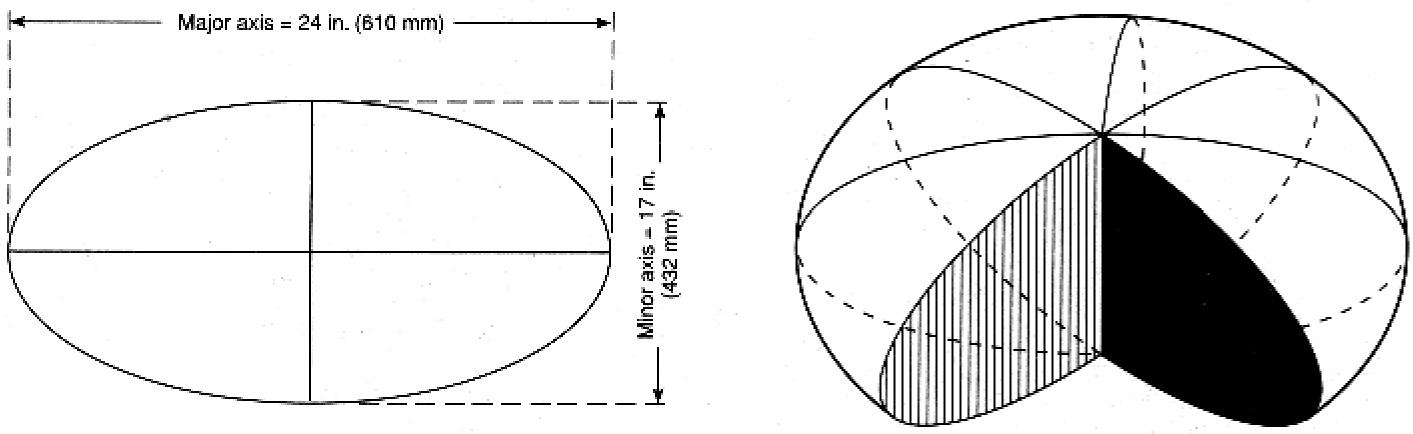


Figure A-3-2.5 Ellipsoid of revolution about a minor axis.

A-3-3.2

Because some smoke detectors are activated by the gases released when cooking food and can result in an unwanted alarm, the smoke detector manufacturer should be consulted regarding the detector's suitability for operation in close proximity to cooking processes.

Appendix B Gas Pipe Sizing

This Appendix is not a part of the requirements of this NFPA document but is included for informational purposes only.

B-2-4.4 Example of Gas Pipe Sizing.

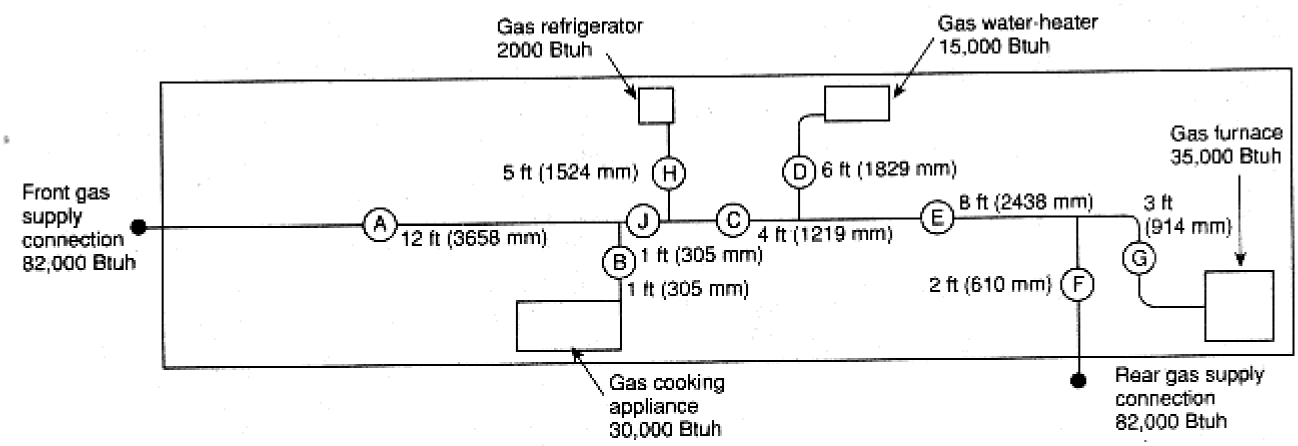


Figure B-2-4.4 Typical example of gas pipe system sizing for a recreational vehicle.

To determine the required gas supply pipe sizes for each piping section of the typical example diagrammed in B-2-4.4, assuming a combination LP-Gas/Natural Gas Supply System, take the following steps:

Table B-2-4.4 Example of Determining Gas Supply Pipe Sizes

Figure Sizing By	Front Gas Supply Connection	Rear Gas Supply Connection
Step 1. Measure the length of the piping from the gas supply connection to the inlet of the most remote appliance.	28 ft (8.5 m) (A + J + C + E + G) [Total: 28,000 Btuh (8204 W)]	19 ft (5.8 m) (F + E + C + H) [Total: 82,000 Btuh (24,026 W)]
Step 2. In the appropriate Table 2-4.4 (a) – (d), select the column showing that distance or the next longer distance if the table does not give the exact length. In this example use Table 2-4.4 (a) since it presumes using a combination LP-Gas/Natural Gas Piping System using iron pipe.	30 ft (9.2 m) column [which for 82,000 Btuh (24,026 W) means ½ in. (13 mm) iron pipe or ¾ in. (19 mm) tubing]	20 ft (6.1 m) column [which for 82,000 Btuh (24,026 W) means ½ in. (13 mm) iron pipe or ¾ in. (19 mm) tubing]
Step 3. Use the vertical column in Table 2-4.4 (a) selected in Step 2 for all gas pipe sizing. For each section of piping, determine the total demand for that section. In the vertical column selected in Step 2 locate the Btuh demand equal to or just greater than the demand for that section of pipe.	30 ft (9.2 m) Column Front Connection (see below)	20 ft (6.1 m) Column Rear Connection (see below)
Step 4. Choose the larger size piping required from either the front or rear gas supply connection. If a single gas supply connection is provided, this step is not required.		

30 ft (9.2 m) Column Front Connection

Piping Section	Btuh Demand (1000's)	(W) Demand	Nominal I.D. Pipe In.	Nominal I.D. Pipe (mm)	Tubing O.D. In.	Tubing O.D. (mm)
A	82	24,026	½	13	¾	19
B	30	8790	⅜	10	½	13
C	50	14,650	⅜	10	⅝	16
D	15	4395	¼	6	⅜	10
E	35	10,255	⅜	10	⅝	16
F	—	—	—	—	—	—
G	35	10,255	⅜	10	⅝	16
H	2	586	¼	6	⅜	10
J	52	15,236	⅜	10	⅝	16

20 ft (6.1 m) Column Rear Connection

Piping Section	Btuh Demand (1000's)	(W) Demand	Nominal I.D. Pipe In.	Nominal I.D. Pipe (mm)	Tubing O.D. In.	Tubing O.D. (mm)
A	—	—	—	—	—	—
B	30	8790	⅜	10	½	13
C	32	9376	⅜	10	½	13
D	15	4395	¼	6	⅜	10
E	47	13,771	⅜	10	⅝	16
F	82	24,026	½	13	¾	19
G	35	10,255	⅜	10	½	13
H	2	586	¼	6	⅜	10
J	30	8790	⅜	10	½	13

1996 Edition

This edition of NFPA 501D, *Standard for Recreational Vehicle Parks and Campgrounds*, was prepared by the Technical Committee on Recreational Vehicles and acted on by the National Fire Protection Association, Inc., at its Fall Meeting held November 13-15, 1995, in Chicago, IL. It was issued by the Standards Council on January 12, 1996, with an effective date of February 2, 1996, and supersedes all previous editions.

Changes other than editorial are indicated by a vertical rule in the margin of the pages on which they appear. These lines are included as an aid to the user in identifying changes from the previous edition.

This edition of NFPA 501D was approved as an American National Standard on February 2, 1996.

Origin and Development of NFPA 501D

The earliest activity of the NFPA in the development of standards for recreational vehicle parks was initiated in 1937 with the first NFPA standard officially adopted in 1940. This standard was entitled *Standard for Trailer Coaches and Trailer Coach Camps*. A revision of the 1940 standard was adopted by NFPA in 1952 (post-World War II), entitled NFPA 501, *Standards for Fire Prevention and Fire Protection in Trailer Coaches and Trailer Coach Courts*. In 1960 the NFPA acted to approve a revised version dividing the earlier text into two parts, one designated NFPA 501A and adopted that year under the title *Standard for Fire Protection in Trailer Courts*; the other, NFPA 501B, adopted in 1971 and entitled *Standard for Fire Prevention and Fire Protection in Mobile Homes and Travel Trailers*. The latter (NFPA 501B) was further amended in 1963. In 1964 a revision of NFPA 501A was approved as the NFPA *Standard for Fire Protection in Trailer Courts.*

During the years 1962-64 arrangements were made to consolidate the separate standards activities of the Mobile Homes Manufacturers Association and the Trailer Coach Association, which had produced standards under the American Standards Association (now ANSI) known as *American Standard Installations of Plumbing, Heating and Electrical Systems in Travel Trailers* (A119.2-1963) and a similar *Standard on Mobile Homes* (A119.1-1963). These inter-organizational arrangements were completed in 1964, and in 1969 the newly formed Recreational Vehicle Institute was added as a fourth co-sponsor.

The first standard covering any aspect of recreational vehicle parks completed by the present ANSI-sponsored committee was the *Electrical Standard for Recreational Vehicle Parks* (NFPA 501D-1971; ANSI A177.2-1972, subsequently redesignated ANSI A119.4-1972). This edition was prepared and published to update the previous material covering electrical safety in the 1964 edition of NFPA 501A, *Standard for Fire Prevention and Fire Protection in Trailer Courts*. In the 1971 edition of NFPA 70, *National Electrical Code®*, electrical requirements for trailer courts first appeared, based largely on NFPA 501D-1971. Since it obviously was necessary to maintain coordination between this standard and NFPA 70, *National Electrical Code*, the sponsoring committees established liaison procedures so that Chapter 6 of the 1977 edition and the content of Part B of Article 551 of NFPA 70, *National Electrical Code*, were identical in intent.

Companion NFPA documents to this standard, besides the *National Electrical Code*, are NFPA 501C, *Standard on Recreational Vehicles*, and NFPA 501A, *Standard for Fire Safety Criteria for Manufactured Home Installations, Sites, and Communities*.

Sponsorship for the 1977 edition of the standard was held jointly by the National Fire Protection Association and the Recreation Vehicle Industry Association. The standard was developed by the Sectional Committee on Recreational Vehicle Parks and Campgrounds, which operated under the Correlating Committee on Mobile Homes and Recreational Vehicles.

The 1977 edition included substantive revisions to the previous edition in Chapter 6 ("Electrical Systems").

The 1982 edition of the *Standard for Fire Safety Criteria for Recreational Vehicle Parks and Campgrounds* superseded the 1977 edition.

The 1982 edition was produced by the newly formed Committee on Fire Safety for Recreational Vehicles (June 20, 1979), which was responsible for developing a standard for fire safety for recreational vehicles and recreational vehicle parks. Therefore, the 1982 edition excluded all sections of the previous editions not considered within the Committee scope. Notably excluded were sections dealing with environmental health and sanitation. Also excluded were requirements for park electrical systems, which are addressed by reference to the *National Electrical Code*.

Modifications also were made in sections dealing with definitions and fire safety and to conform with the NFPA *Manual of Style*.

The 1986 edition included very minor reference changes and revised definitions.

The 1990 edition contained a completely revised chapter on fire safety requirements, Chapter 3, so that non-fire safety items could be moved to other chapters handled by the ANSI A119 Committee. The standard was reconfirmed in 1993, and some sections that were considered operational concerns were deleted from Chapter 3 in this 1996 edition.

NOTICE

Requirements for environmental health and sanitation are developed by the ANSI A119 Committee of which the Recreational Vehicle Industry Association is Secretariat. These requirements and the fire safety requirements of NFPA 501D are published and distributed under one cover as ANSI A119.4/NFPA 501D by ANSI, NFPA, and RVIA.

Technical Committee on Recreational Vehicles

Mark Luttich, *Chair*
Nebraska Dept. of Health, NE

Bruce A. Hopkins, *Secretary*
Recreation Vehicle Industry Assn., VA

Donald D. Bartz, Winnebago Industries, Inc., IA

Joseph M. Bloom, Bloom Fire Investigation, OR

Orville H. Cummings, Florida Bureau of Mobile Home & Rec Vehicle Const., FL

Daniel F. Fitzgerald, State of California, CA

John P. Harvey, State of Washington, WA

Ralph E. Herzler, Majara Corp., MI

Jon O. Jacobson, Jacobson Engr, WA

George E. Kiefer, State of Arizona, AZ

Shawn D. MacGregor, Terralab Engr Int'l, UT

John Pabian, Underwriters Laboratories Inc., IL

Homer Staves, Kampgrounds of America, Inc., MT

Raymond F. Tucker, RADCO, CA

Gary Wight, Park Washington, WA
Rep. Nat'l Assn. of RV Parks & Campgrounds

Robert E. Wozniak, Fleetwood Enterprises, Inc., CA

Patrick Yee, Canadian Standards Assn., ON

Alternates

Christopher J. Bloom, CJB Fire Consultants, OR
(Alt. to J. M. Bloom)

James W. Finch, Kampgrounds of America, Inc., MT
(Alt. to H. Staves)

Kent Perkins, Recreation Vehicle Industry Assn., VA
(Alt. to B. A. Hopkins)

Toby Pimental, State of Arizona, AZ
(Alt. to G. E. Kiefer)

James R. Thiel, Underwriters Laboratories Inc., IL
(Alt. to J. Pabian)

Richard Ortisi-Best, NFPA Staff Liaison

This list represents the membership at the time the Committee was balloted on the text of this edition. Since that time, changes in the membership may have occurred.

NOTE: Membership on a Committee shall not in and of itself constitute an endorsement of the Association or any document developed by the Committee on which the member serves.

Committee Scope: This Committee shall have primary responsibility for documents on the fire safety criteria for recreational vehicles and recreational vehicle parks.

NFPA 501D

Standard for Recreational Vehicle Parks and Campgrounds

1996 Edition

NOTICE: An asterisk (*) following the number or letter designating a paragraph indicates explanatory material on that paragraph in Appendix A.
Information on referenced publications can be found in Chapter 5.

Chapter 1 General

1-1 Introduction.

1-1.1 Need for Standard.

Those members of the recreational vehicle industry, recreational vehicle park owners, and code enforcement officials have been aware of the need for uniform minimum standards for recreational vehicle parks and campgrounds. It is with this thought that the standard has been developed.

1-1.2 Basis for Standard.

Much of the material in this standard has been taken from, or is based on, nationally recognized standards for fire, health, and life safety. Applicable standards are shown in Chapter 5.

1-2 Scope.

The intent of this standard is to provide minimum construction requirements to ensure a reasonable degree of safety and health for occupants using facilities supplied by recreational vehicle parks and campgrounds, which offer temporary living sites for use by recreational vehicles and camping units. This standard shall provide minimum requirements that are applicable, in varying degrees, to recreational vehicle parks and campgrounds, dependent on the intended use for each.

1-2.1 Not Covered.

This standard shall not cover the design of recreational vehicles or other forms of camping units. ANSI A119.2/NFPA 501C, *Standard on Recreational Vehicles*, is a companion standard on which the provisions of this standard are largely based. Operational and maintenance practices for recreational vehicle parks and campgrounds are not included.

1-2.2 Applicability.

This standard has been developed to serve as a basis for regulations by authorities having jurisdiction over the facilities provided in new recreational vehicle parks and campgrounds and additions to existing facilities only. Facilities provided in existing recreational vehicle parks and campgrounds can be continued in use providing such facilities do not constitute a recognized health or safety hazard.

1-2.3 Limitations.

This standard shall not be intended as a design specification or an instruction manual.

1-2.4 Alternate Materials, Equipment, and Procedures.

The provisions of this standard shall not be intended to prevent the use of any material, method of construction, or installation procedure not specifically prescribed by this standard, provided any such alternate is acceptable to the authority having jurisdiction. The authority having jurisdiction shall require that sufficient evidence be submitted to substantiate any claims made regarding the safety of such alternates.

1-2.5 Differing Standards.

Wherever nationally recognized standards and this standard differ, the requirements of this standard shall apply.

1-2.6 U.S. Federal Regulations.

Federal regulations under the National Highway Traffic Safety Administration might supersede all or part of this standard as applied to any category of regulated motor vehicles.

1-3 Definitions.

Approved.* Acceptable to the authority having jurisdiction.

Authority Having Jurisdiction.* The organization, office, or individual responsible for approving equipment, an installation, or a procedure.

Campground. As used in this standard, any parcel or tract of land under the control of any person, organization, or governmental entity wherein sites are offered for the use of the public or members of an organization for the establishment of temporary living sites for two or more recreational vehicles or camping units. Campgrounds can be one of the following types:

Developed Campground. A campground with two or more recreational unit sites accessible by vehicular traffic where sites are substantially developed and refuse disposal systems, flush toilets, bathing facilities, and water are provided.

Fully Developed Campground. A developed campground with one or more service buildings.

Primitive Campground. A campground accessible only by walk-in, pack-in, or equestrian campers where no facilities are provided for the comfort or convenience of the campers.

Semi-Developed Campground. A campground with two or more recreational unit sites, accessible by vehicular traffic. Roads, facilities (toilets and/or privies) are provided.

Semi-Primitive Campground. A campground accessible only by walk-in, equestrian, or motorized trail vehicles where rudimentary facilities (privies and/or fireplaces) might be provided for the comfort and convenience of the campers.

Camping Trailer. A vehicular portable unit mounted on wheels and constructed with collapsible partial side walls that fold for towing by another vehicle and unfold at the campsite to provide temporary living quarters for recreational, camping, or travel use. (*See definition of Recreational Vehicle.*)

Camping Unit. A tent or other type of portable shelter intended, designed, or used for temporary human occupancy.

Camping Unit Site. A specific area within a campground or recreational vehicle park that is set aside for use as a temporary living site by a camping unit. [*See also definition of Recreational Vehicle Site (including A-1-3) and Recreational Unit Site.*]

Developed Campground. (*See definition of Campground.*)

Fifth Wheel Trailer. A vehicular unit, mounted on wheels, designed to provide temporary living quarters for recreational, camping, or travel use, that is of such size or weight as not to require special highway movement permit(s), of gross trailer area not to exceed 400 ft^2 (37.2 m^2) in the set-up mode, and designed to be towed by a motorized vehicle that contains a towing mechanism that is mounted above or forward of the tow vehicle's rear axle. (*See definition of Recreational Vehicle.*)

Fully Developed Campground. (*See definition of Campground.*)

Gross Trailer Area.* The total plan area of a travel trailer measured to the maximum horizontal projection of exterior walls when in the set-up mode.

Labeled. Equipment or materials to which has been attached a label, symbol, or other identifying mark of an organization that is acceptable to the authority having jurisdiction and concerned with product evaluation that maintains periodic inspection of production of labeled equipment or materials and by whose labeling the manufacturer indicates compliance with appropriate standards or performance in a specified manner.

Liquefied Petroleum Gas, LP-Gas, and LPG. Any material having a vapor pressure not exceeding that allowed from commercial propane composed predominantly of the following hydrocarbons, either by themselves or as mixtures: propane, propylene, butane (normal butane or iso-butane), and butylene (including isomers).

Listed.* Equipment or materials included in a list published by an organization acceptable to the authority having jurisdiction and concerned with product evaluation that maintains periodic inspection of production of listed equipment or materials and whose listing states either that the equipment or material meets appropriate standards or has been tested and found suitable for use in a specified manner.

Motor Home. A vehicular unit designed to provide temporary living quarters for recreational, camping, or travel use built on or permanently attached to a self-propelled motor vehicle chassis or on a chassis cab or van that is an integral part of the completed vehicle. (*See definition of Recreational Vehicle.*)

Park Trailer. A recreational vehicle that meets the following criteria:

(a) Built on a single chassis mounted on wheels.

(b) Having a gross trailer area not exceeding 400 ft^2 (37.2 m^2) in the set-up mode.

(c) Certified by the manufacturer as complying with ANSI A119.5, *Standard for Park Trailers*.

Primitive Campground. (*See definition of Campground.*)

Recreational Unit Site. Either a recreational vehicle site or a camping unit site. [*See definition of Recreational Vehicle Site (including A-1-3) and Camping Unit Site.*]

Recreational Vehicle. A vehicular-type unit primarily designed as temporary living quarters for recreational, camping, travel, or seasonal use that either has its own motive power or is mounted on or towed by another vehicle. The basic entities are: travel trailer, camping trailer, fifth wheel trailer, truck camper, park trailer, and motor home. (*See individual definitions.*)

Recreational Vehicle Park. A plot of land where two or more recreational vehicle sites are located, established, or constructed to provide for occupancy by recreational vehicles owned or operated by the general public as temporary living quarters for recreational or vacation purposes.

Recreational Vehicle Site.* A plot of ground within a recreational vehicle park set aside for the accommodation of a recreational vehicle on a temporary basis. It can be used as either a recreational vehicle site or as a camping unit site. (*See definition of Camping Unit Site.*)

Recreational Vehicle Stand. An area completely contained within a recreational vehicle site intended for the placement of a recreational vehicle.

Semi-Developed Campground. (*See definition of Campground.*)

Semi-Primitive Campground. (*See definition of Campground.*)

Service Building. A structure or portion thereof that is used to house sanitary facilities, such as water closets or lavatories. It can include other facilities for the convenience of the owner or the occupants of the recreational vehicle park or campground.

Shall. Indicates a mandatory requirement.

Should. Indicates a recommendation or that which is advised but not required.

Travel Trailer. A vehicular unit, mounted on wheels, designed to provide temporary living quarters for recreational, camping, or travel use and of such size or weight as not to require special highway movement permits when towed by motorized vehicle, and that has a gross trailer area less than 320 ft^2 (28.8 m^2). (*See definition of Recreational Vehicle.*)

Truck Camper. A portable unit constructed to provide temporary living quarters for recreational, travel, or camping use, consisting of a roof, floor, and sides designed to be loaded onto and unloaded from the bed of a pickup truck. (*See definition of Recreational Vehicle.*)

1-4 Units.

Metric units of measurement in this standard shall be in accordance with the modernized metric system known as the International System of Units (SI). Two units (liter and bar), outside of but recognized by SI, are commonly used in international fire protection. These units are listed in Table 1-4.2 with conversion factors.

1-4.1

If a value for measurement as given in this standard is followed by an equivalent value in other units, the first stated shall be regarded as the requirement. A given equivalent value might be approximate.

1-4.2

The conversion procedure for the SI units has been to multiply the quantity by the conversion factor and then round the result to the appropriate number of significant digits.

Table 1-4.2

Name of Unit	Unit Symbol	Conversion Factor
liter	L	1 gal = 3.785 L
liter per minute per square meter	$L/min/m^2$	1 gpm/ft^2 = 40.746 $L/min/m^2$
cubic decimeter	dm^3	1 gal = 3.785 dm^3
pascal	Pa	1 psi = 6894.757 Pa
bar	bar	1 psi = 0.0689 bar 1 bar = 10^6 Pa

1-5 Electrical Requirements.

All electrical installations, systems, and equipment shall comply with Article 551, Part (B) and other applicable sections of NFPA 70, *National Electrical Code*®.

Chapter 2 General Design Criteria for Recreational Vehicle Parks and Campgrounds

Requirements for general design criteria for recreational vehicle parks and campgrounds are developed by the ANSI A119 Committee, of which the Recreational Vehicle Industry Association is Secretariat. These requirements and the fire safety requirements in this standard are published and distributed under one cover as ANSI A119.4/NFPA 501D.

Chapter 3 Fire Safety

3-1 Fire Detection and Alarm Services.

3-1.1 Water Supplies for Fire Protection.

Water supplies for fire protection purposes shall meet the requirements of the authority having jurisdiction. (*See also NFPA 1231, Standard on Water Supplies for Suburban and Rural Fire Fighting.*)

3-1.2 Detection Systems in Structures Open to the Public.

Fire detection and alarm systems installed in structures open to the public shall be installed in accordance with NFPA 72, *National Fire Alarm Code*.

3-1.3 Fire Extinguishers.

Portable fire extinguishers provided by the recreational vehicle park or campground operator shall be of the multipurpose dry chemical type or equal. Such extinguishers shall have a minimum rating of 2A:20B:C and shall be installed in accordance with NFPA 10, *Standard for Portable Fire Extinguishers*.

3-1.4 Use of Fire Protection Equipment.

The recreational vehicle park and campground operator shall instruct the park staff in the use of the fire protection equipment available in the park and define the staff's specific duties in the event of fire.

3-1.5 Evacuation Plan.

Each recreational vehicle park and campground shall have a written evacuation plan approved by the authority having jurisdiction.

3-1.6 Campfire Locations.

Designated outdoor campfire locations, if provided, shall be in safe and convenient areas where they will not constitute fire hazards to vegetation, undergrowth, trees, recreational vehicles, recreational park trailers, camping units, and structures.

3-2 Fire Safety Rules and Regulations for Recreational Vehicle Parks and Campgrounds.

3-2.1 Posting of Emergency Information.

Fire safety rules and regulations shall be conspicuously posted by management. These regulations shall contain the following information and any additional information as required by the fire department.

(a) The telephone number of the fire department or other information needed for summoning the fire department, such as the location of the nearest fire alarm box.

(b) The telephone number of the police department.

(c) The telephone number of the recreational vehicle park or campground (or any other data that would aid in ensuring prompt fire department response, such as the recreational vehicle park or campground name and address).

(d) The location of the nearest public telephone.

3-2.2 Refuse.

A refuse disposal system shall be provided.

Chapter 4 Environmental Health and Sanitation

Requirements for environmental health and sanitation are developed by the ANSI A119 Committee, of which the Recreational Vehicle Industry Association is Secretariat. These requirements and the fire safety requirements in this standard are published and distributed under one cover as ANSI A119.4/NFPA 501D.

Chapter 5 Referenced Publications

5-1

The following documents or portions thereof are referenced within this standard and shall be considered part of the requirements of this document. The edition indicated for each reference is the current edition as of the date of the NFPA issuance of this document.

5-1.1 NFPA Publications.

National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.

NFPA 10, *Standard for Portable Fire Extinguishers*, 1994 edition.

NFPA 70, *National Electrical Code*, 1996 edition.

NFPA 72, *National Fire Alarm Code*, 1993 edition.

NFPA 501C, *Standard on Recreational Vehicles*, 1996 edition.

NFPA 1231, *Standard on Water Supplies for Suburban and Rural Fire Fighting*, 1993 edition.

5-1.2 Other Publications.

5-1.2.1 ANSI Publications. American National Standards Institute, Inc., 1430 Broadway, New York, NY 10018.

ANSI A119.2/NFPA 501C, *Standard on Recreational Vehicles*, 1996.

ANSI A119.5, *Standard for Park Trailers*, 1993.

5-1.2.2 ASTM Publication. American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103.

ASTM E 380, *Standard Practice for Use of the International System of Units (SI) (the Modernized Metric System)*, 1993.

Appendix A Explanatory Material

This Appendix is not a part of the requirements of this NFPA document but is included for informational purposes only.

A-1-3 Approved.

The National Fire Protection Association does not approve, inspect, or certify any installations, procedures, equipment, or materials; nor does it approve or evaluate testing laboratories. In determining the acceptability of installations, procedures, equipment, or materials, the authority having jurisdiction may base acceptance on compliance with NFPA or other appropriate standards. In the absence of such standards, said authority may require evidence of proper installation, procedure, or use. The authority having jurisdiction may also refer to the listings or labeling practices of an organization concerned with product evaluations that is in a position to determine compliance with appropriate standards for the current production of listed items.

A-1-3 Authority Having Jurisdiction.

The phrase “authority having jurisdiction” is used in NFPA documents in a broad manner, since jurisdictions and approval agencies vary, as do their responsibilities. Where public safety is primary, the authority having jurisdiction may be a federal, state, local, or other regional department or individual such as a fire chief; fire marshal; chief of a fire prevention bureau, labor department, or health department; building official; electrical inspector; or others having statutory authority. For insurance purposes, an insurance inspection department, rating bureau, or other insurance company representative may be the authority having jurisdiction. In many circumstances, the property owner or his or her designated agent assumes the role of the authority having jurisdiction; at government installations, the commanding officer or departmental official may be the authority having jurisdiction.

A-1-3 Gross Trailer Area.

In calculating the square footage, measurements should be taken on the exterior. Square footage includes all siding, corner trims, moldings, storage spaces, areas enclosed by windows but not the roof overhangs (Ref. HUD Interpretive Bulletin A-1-88).

Expandable room sections, regardless of height should be included. Storage lofts contained within the basic unit should have ceiling heights less than 5 ft (1.5 m) and would not constitute additional square footage.

A-1-3 Listed.

The means for identifying listed equipment may vary for each organization concerned with product evaluation, some of which do not recognize equipment as listed unless it is also labeled. The authority having jurisdiction should utilize the system employed by the listing organization to identify a listed product.

A-1-3 Recreational Vehicle Site.

The term “recreational unit site” (*see definition*) is used in this standard when it is desired to describe conditions that apply equally to a “recreational vehicle site” and to a “camping unit site” (*see definitions*).

NFPA 502

1996 Edition

Recommended Practice on Fire Protection for Limited Access

Highways, Tunnels, Bridges, Elevated Roadways, and Air

1996 Edition

This edition of NFPA 502, *Recommended Practice on Fire Protection for Limited Access Highways, Tunnels, Bridges, Elevated Roadways, and Air Right Structures*, was prepared by the Technical Committee on Motor Vehicle and Highway Fire Protection and acted on by the National Fire Protection Association, Inc., at its Annual Meeting held May 20-23, 1996, in Boston, MA. It was issued by the Standards Council on July 18, 1996, with an effective date of August 9, 1996, and supersedes all previous editions.

This edition of NFPA 502 was approved as an American National Standard on July 26, 1996.

Origin and Development of NFPA 502

A tentative standard, NFPA 502T, *Standard for Limited Access Highways, Tunnels, Bridges and Elevated Structures*, was prepared by the Technical Committee on Motor Vehicle Fire Protection and was adopted by the National Fire Protection Association on May 16, 1972 at its Annual Meeting in Philadelphia, PA. It was withdrawn in November 1975. In 1980, the Committee rewrote the document as a Recommended Practice and included a chapter on Air Right Structures. It was adopted at the 1981 Annual Meeting.

Minor revisions to Chapters 2 through 5, primarily water supply and fire apparatus requirements, were made in the 1987 edition.

The recommended practice was reconfirmed in 1992.

The recommended practice was revised in 1996 to incorporate a totally revised chapter on tunnels and make other revisions and changes to correlate the new material in tunnel and air right structure requirements with existing chapters in the document.

The reworking of the document as related to tunnels and air right structures was to bring it up to current technology and practices.

The development of this 1996 edition was accomplished by an NFPA 502 Task Group appointed by the Chairman of the Technical Committee in October 1993. This task group effort was conducted by the following individuals:

Arthur G. Bendelius, Task Group Chair, Parsons Brinckerhoff, NY; Dennis J. Becker, Richard D. Kimball Co., Inc., MA; Anthony S. Caserta, U.S. Federal Highway Administration, DC; William G. Connell, Parsons Brinckerhoff, MA; Stephan K. Dunbar, Boston Fire Dept., MA; Phillip Egilsrud, Consultant, MO; William A. Eppich, Protectowire Co., MA; John P. Kenney, Boston Fire Dept., MA; Maurice M. Pilette, Mechanical Designs, Ltd., MA.

Technical Committee on

Motor Vehicle and Highway Fire Protection

Enoch Lipson, *Chair*
The Port Authority of New York & New Jersey, NY

Dennis J. Becker, Richard D. Kimball Co., Inc., MA

Neill Darmstadter, American Trucking Assn. Inc., VA

A. L. Elliott, Sacramento, CA

William A. Eppich, The Protectowire Co., Inc., MA

Edward E. Friloux, Sr., American Fire Retardant Corp., LA

Clifford J. Harvison, Nat'l Tank Truck Carriers Inc., VA

Maurice M. Pilette, Mechanical Designs Ltd., MA

George E. Ralph, Southport, ME

Steven R. Shinners, Yellow Freight System, Inc., KS

Michael P. Wilson, American Insurance Services Group Inc., NY

Alternate

Arthur G. Bendelius, Parsons Brinckerhoff, NY
(Alt. to A. L. Elliott)

Richard Ortisi-Best, NFPA Staff Liaison

This list represents the membership at the time the Committee was balloted on the text of this edition. Since that time, changes in the membership may have occurred.

NOTE: Membership on a Committee shall not in and of itself constitute an endorsement of the Association or any document developed by the Committee on which the member serves.

Committee Scope: This Committee shall have primary responsibility for documents on motor vehicle fire prevention and protection measures to reduce loss of life and property damage in the operation and maintenance (repair) of such vehicles (except as specified herein); fire prevention and protection recommendations for motor freight terminals; protection for tunnels, air right structures, and bridges; and to recommend protection facilities on limited access highways. Included as motor vehicles are trucks, buses, taxicabs, limousines, and passenger cars; excluded are the design, fire protection, and operational procedures for fire apparatus, mobile homes and travel trailers, tank vehicles of all kinds for handling flammable and combustible liquids and liquefied petroleum gases, and vehicles transporting explosives and other hazardous chemicals. The construction and protection of garages is handled by the NFPA Committee on Garages.

NFPA 502
Recommended Practice on Fire Protection for

Limited Access Highways, Tunnels, Bridges, Elevated Roadways, and Air Right Structures

1996 Edition

NOTICE: An asterisk (*) following the number or letter designating a paragraph indicates explanatory material on that paragraph in Appendix A.
Information on referenced publications can be found in Chapter 11 and Appendix H.

Chapter 1 General

1-1 Scope.

This recommended practice is intended primarily for the guidance of those individuals responsible for the design, construction, operation, maintenance, and fire protection of limited access highways, tunnels, bridges, elevated roadways, depressed roadways, and air right structures. It also applies, to a lesser extent, to buildings and structures that are exposed to the hazards of the operational zones.

1-1.1

This recommended practice does not apply to requirements for the following:

(a) Parking garages;

(b) Bus terminals;

(c) Truck terminals;

(d) Any other facility in which motor vehicles travel or are parked.

1-1.2

To the extent where a facility, including those listed in 1-1.1(a) through (d), introduces hazards of a similar nature to those addressed in this document, this recommended practice can be used as a guide.

1-2 Purpose.

The purpose of this document is to establish minimum criteria that provide a reasonable degree of protection from fire and its related hazards.

1-3 Equivalency.

Nothing in this recommended practice is intended to prevent the use of systems, methods, or devices that are of equivalent or superior quality, strength, fire resistance, effectiveness, durability, and safety to those prescribed by this recommended practice, provided technical documentation is submitted to the authority having jurisdiction to demonstrate equivalency and provided the system, method, or device is approved for the intended purpose.

1-4 Characteristics of Fire Protection.

Fire protection on limited access highways, in tunnels, and on bridges is achieved through a composite of facility design, operating equipment, hardware, software, subsystems, and procedures integrated to provide requirements for the protection of life and property from the effects of fire. The level of fire protection desired for the entire facility should be achieved by integrating the requirements developed through use of this document for each subsystem.

1-5 Application.

1-5.1

The provisions of this document are considered necessary to provide a reasonable level of protection from loss of life and property from fire and explosion. They reflect the practices and the state of the art prevalent at the time this recommended practice was issued.

1-5.2

Unless otherwise noted, it is not intended that the provisions of this document be applied to facilities, equipment, structures, or installations that were existing or approved for construction or installation prior to the effective date of this recommended practice, except in those cases where it is determined by the authority having jurisdiction that the existing situation involves a distinct hazard to life or adjacent property.

1-5.3

Application of this recommended practice to alterations should be determined by the authority having jurisdiction.

1-5.4

That portion of this document that covers emergency procedures does apply to both new and existing facilities.

1-5.5

This recommended practice also can be used for upgrading fire protection facilities, except in those instances where compliance with this recommended practice is not practical or possible within the limits of the existing structure.

1-6 Safeguards During Construction.

During the course of construction or major modification of any limited access highway, tunnel, or bridge structure, the provisions of NFPA 241, *Standard for Safeguarding Construction, Alteration, and Demolition Operations,* should apply.

1-7 Limited Access Highways.

1-7.1

Limited access highways present two fire protection problems. One is the protection of life and property transported by vehicles traveling on the facility, and the other is the protection of permanent installations located on, over, below, or adjacent to the facility. Protection to life is to be given primary consideration in all cases. Protection of the facility is also of major importance because of its vital role in the community.

1-7.2

Protection of related facilities such as service areas, rest areas, toll booths, and buildings used for administration, law enforcement, and maintenance presents problems that are not basically different from the fire protection problems of all such buildings. However, special consideration should be given to the fact that on, or adjacent to, limited access highways, such buildings might be located in isolated areas. (*See NFPA 30, Flammable and Combustible Liquids Code, and NFPA 30A, Automotive and Marine Service Station Code, for service stations*.)

1-7.3

Protection for people and property transported by vehicles is somewhat more complicated, since the location of emergencies cannot be predetermined; emergencies can occur at any point or simultaneously at several points along the course of any vehicle transport facility. Fire emergencies can range from incipient fires in passenger vehicles to major accidents involving loaded buses and trucks carrying hazardous materials. Heavy traffic, adverse weather conditions, and night usage escalate the problem.

1-7.4

Studies of fire protection for limited access highways indicate that there are three interdependent factors to be considered. The first is the rapid transmission of alarms to the proper authorities and a simultaneous warning to approaching vehicle operators. The second is the response of appropriate apparatus and fire-fighting personnel with minimal delay. The third is the matter of rescue operations followed by fire extinguishment or control. Where life is endangered by fire, the possibility of effective rescue operations decreases rapidly with any delay.

1-7.5

Unless an effective means of communication is provided, the reporting of fire and other emergencies by occupants of passing vehicles has little value. The distance to interchanges, service areas, and toll booths, and indecision due to lack of familiarity with such emergencies, often consumes the limited time that exists for effective action.

1-7.6

Control of traffic is a continuous problem from the start of any emergency to the time at which the occupants and vehicle(s) are removed from the facility.

1-7.7

Fire protection for limited access highways is addressed in Chapter 2.

1-8 Bridges and Elevated Roadways.

1-8.1

A fire occurring on an elevated roadway or bridge has the same characteristics as a fire occurring on a highway, but it usually is less accessible due to the elevated structure.

1-8.2

Protection of life is the primary concern. However, protection of the elevated roadway or bridge might be more important than protection of vehicles and cargo. Damage to a critical structural member from collision or exposure to high temperatures could result in dangerous weakening or complete collapse of the elevated roadway or bridge.

1-8.3

Approaches to elevated structures and bridges frequently pass directly over congested residential or high-value industrial areas. Certain hazardous materials fires on the structures could result in serious exposure fires in the occupancies beneath and in close proximity to the structures. Conversely, these occupancies, particularly those dealing with hazardous materials, can seriously expose the structures.

1-8.4

Fire protection for bridges and elevated roadways is addressed in Chapter 3.

1-8.5

Consideration is to be given to the fact that flammable liquids or vapors can flow from the roadway by gravity and thus extend the fire risk well beyond the area of the original emergency.

1-9 Depressed Roadways.

1-9.1

A depressed roadway is defined as an uncovered, below-grade roadway where emergency response access is limited or a "boat section" where walls rise to the surface above the roadway surface.

1-9.2

A fire occurring in a depressed highway poses problems similar to those of a fire in a bridge or elevated roadway, with restricted access to the scene of the fire due to the containing walls.

1-9.3

Since the majority of depressed roadways are associated with tunnels as connecting sections or open approaches, depressed roadways are addressed in Chapter 4.

1-10 Tunnels.

1-10.1

The fire protection problem created by a fire in a highway tunnel is similar to that of a fire occurring on a highway in that the emergency is complicated by existing traffic conditions, the number of passengers carried by involved vehicles, and the wide diversity of cargo transported by trucks.

A fire in a tunnel can be extremely destructive and dangerous because the confined space hinders the dissipation of heat and smoke. Additional problems connected with a fire emergency in a tunnel include access limitations for fire-fighting equipment and personnel, early fire detection and alarm transmission, control of traffic, and evacuation of the public from an enclosed facility.

1-10.2

Protection of life is the primary concern. Access points for fire personnel, emergency egress for motorists, fire detection and alarm systems designed to meet the demands of tunnel application, availability of water supply, and adequate ventilation capabilities are among the fundamentals that are to be considered in providing adequate safeguards for both the motorists and the fire fighters to help cope in an emergency. The secondary consideration is protection of the tunnel structure itself. Damage to the ventilation, lighting, or fire suppression systems can endanger lives.

1-10.3

As in the case of highways, the primary need is a means for prompt and rapid detection and notification to the authorities of the existence and location of an emergency and the development of effective response plans, reliable communications, and means of traffic control.

1-10.4

Every tunnel has its own unique characteristics. Tunnels vary in length, cross section, profile, traffic operations, and traffic volumes, among other characteristics. Tunnels can be found in either urban or rural environments and can be subaqueous, subterranean, or mountain type. Therefore, it is imperative that each of these characteristics be considered when establishing emergency/life safety system requirements.

1-10.5

For the purpose of this recommended practice, tunnel length should dictate minimum requirements as follows:

(a) Where the tunnel length exceeds 300 ft (90 m), a standpipe system should be installed to ensure that no point along the tunnel roadway is more than 150 ft (45 m) from a hose connection.

(b) Where the tunnel length exceeds 800 ft (240 m), whereby the maximum distance from any point within the tunnel to an area of safety exceeds 400 ft (120 m), all provisions of this recommended practice should apply.

1-10.6

Fire protection for tunnels is addressed in Chapter 4.

1-11 Air Right Structures.

1-11.1

Where a building is constructed using the air rights over an active motor roadway, the facility begins to resemble a tunnel from the fire protection standpoint. If the sides of the facility are closed, then the air right structure is to be considered a tunnel.

Where an air right structure is fully enclosed on both sides of the roadway, it should be treated, from a fire protection standpoint, as a tunnel. Where the air right structure is not fully enclosed, the decision to treat it as a tunnel should be made by the authority having jurisdiction after sufficient engineering analysis.

1-11.2

Air right structures, as defined in 1-11.1, present two distinctly different fire protection problems. One relates to the persons and property in the structure built above the roadway. The other relates to the persons and property using the roadway that passes under or adjacent to the air right structure.

Fire protection for structures built over the roadway presents problems similar to those involving like buildings in other locations. However, these problems can be complicated by limited access, traffic congestion, and the fire situation on the roadway under or adjacent to the structure.

1-11.3

Fire protection for the roadway under an air right structure is similar to that needed for a tunnel. Occupancy and use of the space above the ceiling of the roadway is significantly different, as outlined in 1-11.2.

1-11.4

While protection of life is the primary consideration, there are other important concerns. The structural members that support the air right building could be subjected to very high temperatures, particularly in a flammable liquids fire or explosion. Damage to these members could have a serious effect on the building. In addition, openings from the roadway such as ventilation shafts and access/egress stairways could allow the passage of flammable vapors to the air right structure with subsequent damage from fire or explosion.

1-11.5

Consideration is to be given to the fact that flammable liquids or vapors can flow from the roadway by gravity or via the drainage system and thus extend the fire risk well beyond the area of the original emergency.

1-11.6

Major structural elements that support an air right structure could be subject to physical damage from motor vehicle accidents.

1-11.7

Fire protection for air right structures is addressed in Chapter 5.

1-12 Units.

1-12.1*

Metric units of measurement in this standard are in accordance with the modernized metric system known as the International System of Units (SI). The liter unit, which is outside of but recognized by SI, is commonly used in international fire protection.

1-12.2

If a value for measurement as provided in this recommended practice is followed by an equivalent value in other units, the first stated value is to be regarded as the recommendation. A given equivalent value might be an approximation.

1-12.3

SI units have been converted by multiplying the value by the conversion factor and rounding the result to the appropriate number of significant digits.

1-13 Definitions.

Agency. The organization legally established and authorized to operate a facility.

Air Right Structure. The roadway facility created when a building is built over the roadway using the roadway's air rights.

Alternate Central Supervising Station. A prearranged location that is equipped, or that can quickly be equipped, to function as the central supervising station in the event the central supervising station is inoperative or untenable for any reason.

Alternative Fuels. Motor vehicle fuels other than gasoline and diesel.

Ancillary Facility. The structure usually used to house or contain operating, maintenance, or support equipment and functions.

Approved.* Acceptable to the authority having jurisdiction.

Authority Having Jurisdiction.* The organization, office, or individual responsible for approving equipment, an installation, or a procedure.

Backlayering. The reversal of the movement of smoke and hot gases contrary to the direction of the ventilation airflow.

Bridge. A structure spanning and providing a roadway across an obstacle such as a waterway, railroad, or another roadway.

Building. Any structure used or intended for supporting or sheltering any use or occupancy. The term building should be construed as if followed by the words "or portions thereof."

Central Supervising Station. The operations center where the authority controls and coordinates the facility operations from which communication is maintained with supervisory and operating personnel of the authority and with participating agencies where required.

Combustible. Capable of undergoing combustion.

Command Post. The location during an emergency, selected by the person in command, for controlling and coordinating the emergency operation.

Communications. Radio, telephone, and messenger services throughout the facility and particularly at the central supervising station and command post.

Control Valve. A valve used to control the water supply system of a standpipe system.

Critical Velocity. The minimum steady-state velocity of the ventilating airflow moving toward the fire, within a tunnel, that is necessary to prevent backlayering.

Dry Standpipe. A standpipe system designed to have piping contain water only while the system is being utilized.

Elevated Roadway. A roadway that is constructed on a structure that is located above the surface but that is not a bridge.

Emergency Procedures Plan. A plan developed by the authority with the cooperation of all participating agencies detailing specific actions to be performed by all those who are to respond during an emergency.

Engineering Analysis. An analysis that evaluates all the various factors that affect the fire safety of the facility or component. A written report of the analysis should be submitted to the authority indicating the fire protection method(s) recommended that will provide a level of fire safety commensurate with this recommended practice.

Facility. As used in this recommended practice, this includes limited access highways, tunnels, bridges, elevated roadways, and air right structures.

Fire Department Connection. A connection through which the fire department can pump water into the standpipe system.

Fire Emergency. The existence of, or threat of, fire or the development of smoke or fumes, or any combination thereof, that calls for immediate action to correct or alleviate the condition or situation.

Hose Connection. A combination of equipment provided for connection of a hose to the standpipe system that includes a hose valve with a threaded outlet.

Hose Valve. The valve to an individual hose connection.

Incidental Occupancy. A facility used by others who are neither employees nor motorists.

Labeled. Equipment or materials to which has been attached a label, symbol, or other identifying mark of an organization that is acceptable to the authority having jurisdiction and concerned with product evaluation that maintains periodic inspection of production of labeled equipment or materials and by whose labeling the manufacturer indicates compliance with appropriate standards or performance in a specified manner.

Latching-Type Detector. A detector circuit configuration in which the detector cannot reset itself once it is in alarm mode. The only way of resetting (restoring) the detector to normal operating mode is at the fire alarm control panel.

Length of Tunnel. The length measured from face of portal to face of portal using the centerline alignment along the tunnel roadway.

Limited Access Highway. A highway where preference is given to through traffic by providing access connections using only selected public roads and by prohibiting crossings at grade and direct private driveways.

Listed.* Equipment, materials, or services included in a list published by an organization acceptable to the authority having jurisdiction and concerned with evaluation of products or services that maintains periodic inspection of production of listed equipment or materials or periodic evaluation of services and whose listing states either that the equipment, material, or service meets identified standards or has been tested and found suitable for a specified purpose.

Motorist. A motor vehicle occupant, including both the driver and passenger.

MUTCD. *Manual on Uniform Traffic Control Devices for Streets and Highways.*

Noncombustible Material. A material that, in the form in which it is used and under the conditions anticipated, does not aid combustion or add appreciable heat to an ambient fire. Materials, where tested in accordance with ASTM E 136, *Standard Test Method for Behavior of Materials in a Vertical Tube Furnace at 750 Degrees C*, and conforming to the criteria contained therein are to be considered as noncombustible.

Participating Agency. A public, quasi-public, or private agency that has agreed to cooperate with and assist the authority during an emergency.

Person-in-Command. A person designated by the authority or a responsible fire or police representative on the scene of an emergency who is fully responsible at the command post.

Point of Safety.* An enclosed fire exit that leads to a public way or safe location outside the structure, or an at-grade point beyond any enclosing structure, or another area that affords adequate protection for motorists.

Portal. The interface between a tunnel and the atmosphere through which vehicles pass.

Power Substation. An arrangement of electrical equipment that does not generate electricity but receives and converts or transforms generated energy to usable electric energy.

Replace-in-Kind. To furnish with new parts or equipment, as applied to equipment and facilities, of the same type but not necessarily of identical design.

Should. Indicates a recommendation or that which is advised but not required.

Structures. Includes, but is not limited to, buildings, bridges, and underground installations.

Tunnel. An enclosed roadway for vehicular traffic with vehicular access limited to portals.

Chapter 2 Limited Access Highways

2-1 General.

The limited access highway poses unique challenges for the fire fighter. The primary problem is the limitation of access to the facility and the possible remote location of the highway.

2-2

Alarm Transmission. Alarm transmission can be provided by the installation of outdoor-type telephone boxes, coded alarm telegraph stations, radio transmitters, sensing equipment, or other suitable devices. The means of transmission should be made conspicuous by indicating lights or other suitable markers and should be located in a way that allows users to park their vehicles clear of the roadway.

Mile markers or other readily available location reference markers should be installed along the highway to allow motorists to provide authorities with reasonably accurate locations for accident or emergency areas.

2-3 Fire Protection.

2-3.1

Arrangements for the response of nearby fire companies and emergency squads should be made. Means of access that allows the entrance of outside aid companies to the facility should be provided, and procedures for utilizing such access should be included in the emergency plan. Appropriate precautions should be taken at these points of entry to alert and control traffic to allow safe entrance by emergency equipment. It is important that fire apparatus responding to fires on limited access roads be equipped with booster tanks [500 gal (1900 L) minimum] and foam-production equipment or an equivalent amount of dry chemical.

2-3.2

All ancillary facilities that support the operation of limited access highways such as maintenance/service buildings, toll plazas, pump stations, and electrical substations should be protected as required by all applicable NFPA standards and local building codes.

2-3.3

Fire extinguishers should be provided at highway installations and buildings in accordance with NFPA 10, *Standard for Portable Fire Extinguishers*.

2-4 Emergency Planning.

2-4.1

It is important that a designated authority carry out a complete and coordinated program of fire protection that includes written preplanned response and standard operating procedures.

2-4.2*

Emergency traffic control procedures should be established to regulate traffic.

2-4.3

To derive the maximum benefit from the fire protection program, comprehensive training programs are necessary for all personnel and agencies expected to participate in fire-fighting operations and hazardous materials emergencies. Such a program should involve a competent supervisory staff experienced in fire-fighting techniques and hazardous materials emergencies.

2-4.4

Contacts should be made with roadside businesses and responsible persons living along limited access highways to elicit their cooperation in the reporting of fires and other emergencies. The objective of such contacts should be to establish a positive system for the reporting of emergencies. Those who agree to participate in the system are to be provided with specific information on the procedures for reporting and a means for determining and reporting the location of the emergency as precisely as possible.

2-4.5

Emergency procedures and the development of an emergency response plan are addressed in Chapter 9.

Chapter 3 Bridges and Elevated Roadways

3-1 General.

Elevated roadways and bridges pose both a vertical and a horizontal access problem for fire-fighting activities. In addition, the potential for a fire under the structure that impacts the integrity of the structure is to be considered.

3-2 Alarm Transmission.

3-2.1

Alarm transmission can be provided by the installation of outdoor-type telephone boxes, coded alarm telegraph stations, radio transmitters, sensing equipment, or other suitable devices. The means of transmission should be made conspicuous by indicating lights or other suitable markers and should be located in a way that allows users to park their vehicles clear of the roadway.

Signs or mile markers should be installed along the bridge to allow motorists to provide authorities with reasonably accurate locations for accident or emergency areas.

3-2.2

A traffic control procedure should be established so that vehicles will either stop or proceed with caution. It is essential that traffic does not block or otherwise interfere with the response of emergency and fire equipment.

3-3 Fire Apparatus, Standpipe Systems, Water Supplies, and Equipment.

Suitable fire apparatus should be available within 1 mi (1.6 km) of all points on elevated roadways and bridges in urban areas; use of ladders by municipal fire fighters may be permitted where elevated structures and bridges are accessible from beneath. The design of apparatus intended for use only on bridges or elevated structures should be based on the conditions encountered. Apparatus responding to fires on bridges and elevated roadways should be equipped with potassium bicarbonate-based dry chemical/aqueous film-forming foam (AFFF) or similar self-contained fire-fighting equipment. In addition, the vehicle should have booster tanks [500 gal (1900 L) minimum].

3-3.1

The responding fire apparatus should be equipped to deliver a foam solution at a minimum rate of 125 gpm (475 L/min) for a minimum duration of 15 minutes. If hydrant or standpipe water is not available, suitable arrangements should be made to transport water in tankers so that the delivery rate of foam can be maintained. Additional supplies of foam should be readily available from mutual aid fire departments or other sources so that the application can be continued for an additional 45 minutes if necessary. These units also should carry multipurpose dry chemical extinguishers and an extinguishing agent for Class D metal fires. Mutual aid, supplier, or manufacturer reserve capability should be available.

3-3.2

In urban locations, hose outlets (hydrants) from the municipal water supply should be located at both ends of bridges. Where more than one agency has the responsibility for providing fire protection, every effort should be made to standardize hose connectors. If this is not possible, suitable adapters should be readily available. In addition, where the length or width of the bridge is such that hose lines of more than 400 ft (120 m) cannot be provided from the hydrants, a standpipe system, in accordance with Chapter 6, should be provided. In certain instances, it might be desirable for duplicated systems to be installed on each side of the roadway and to be cross-connected. Where freezing conditions prevail, systems should be of the dry type. Signs should indicate the location of street-level hydrants.

3-3.3

Sand should be provided for use during icy weather conditions. Suitable absorbent materials should be provided for controlling the spill of hazardous materials. On bridges and elevated roadways, consideration should be given to drainage systems to channel spilled hazardous materials to areas that cannot cause additional hazards. For example, expansion joints should be designed to prevent spillage to the area below.

3-4 Control of Hazardous Materials.

Control of hazardous materials is addressed in Chapter 10.

3-5 Emergency Planning.

3-5.1

It is important that a designated authority carry out a complete and coordinated program of fire protection that should include preplanned emergency response procedures to be contained in an emergency response plan.

3-5.2

To derive the maximum benefit from the fire protection program, comprehensive training programs are necessary for all personnel and agencies expected to participate in fire-fighting operations and hazardous materials emergencies. Such a program should involve a competent supervisory staff experienced in fire-fighting techniques and hazardous materials emergencies.

3-5.3

Emergency procedures and the development of an emergency response plan are addressed in Chapter 9.

Chapter 4 Tunnels

4-1 General.

A tunnel is an enclosed roadway for motor vehicle traffic in which access is limited to portals, which poses some unique fire-fighting challenges due to both the restricted access to the fire site and the confined nature of a tunnel.

4-2 Detection and Alarm.

4-2.1

At least one and preferably two means should be provided to detect fire and transmit an alarm to a local 24-hour monitoring facility, an approved central station, or the local fire department.

4-2.1.1 Manual fire alarm pull stations of the double-action type that are mounted on weatherproof boxes should be installed at intervals of not more than 300 ft (100 m) and at all cross passages and means of egress from the tunnel. The stations should be accessible to both the public and tunnel personnel. The manual fire alarm pull stations should be made conspicuous by lights installed directly above each pull station. Pull stations should be reset with a key. All manual fire alarm pull stations should use an identical key. Each alarm should be transmitted to a local 24-hour monitoring facility, an approved central station, or the local fire department. The alarm is to indicate the location of the pull station. Confirmation of receipt of the sent alarm should be provided at the pull station by a light. Voice communication at the pull station should be considered if a local 24-hour monitoring facility is available.

4-2.1.2 Closed-circuit television systems (CCTV) together with traffic flow indication should be used to detect and identify fires only in tunnels with 24-hour, full-time supervision. Rooms within ancillary structures (pump rooms, utility rooms, cross passages, ventilation structures) and areas not covered by CCTV should be supervised by automatic fire alarm systems.

4-2.1.3 Manual fire alarm pull stations or automatic fire alarm systems should be used in tunnels without 24-hour, full-time supervision. The systems should be in compliance with NFPA 72, *National Fire Alarm Code.*

Exception: Signals for the purpose of evacuation and relocation of occupants are not necessary.

4-2.2

Fire detection in an automatic fire alarm system should identify the location of the fire clearly and should identify the device initiating any alarm (false or otherwise) clearly. The initiating device should have a light that remains on until the device is reset. Automatic fire detection should be provided in all normally unoccupied spaces such as utility rooms, cross passages, stairways, and ventilation structures.

Automatic fire detection within the tunnel should be zoned to correspond with the tunnel ventilation zones and should also identify the location of the fire to within 50 ft (15.3 m).

Portals should be provided with a remote fire alarm annunciator panel at a suitable location accessible to the fire service. Remote annunciator panels should indicate the zone in alarm and should display the location of that alarm.

4-2.3 Fire Alarm Control Panel.

Means should be provided for the installation of a fire alarm control panel (FACP). The FACP should be zoned and should be of the positive, noninterfering, successive (PNIS) type. One zone entering into an alarm should not interfere with any other zone entering into an alarm and should annunciate all alarms. The FACP should have battery backup power. All FACP should be locked, should use an identical key, and should be in compliance with NFPA 72, *National Fire Alarm Code*. The fire alarm zones should correspond to the ventilation zones in the tunnel. The FACP should be in a suitable enclosure for the environment. The FACP should be approved. All FACPS should be fed by a single-phase, three-wire system. The circuit breakers protecting this system should not be configured in a common trip mode of operation. Each circuit breaker should operate independently of all other circuit breakers.

4-2.4 Inspection, Testing, and Maintenance.

Means should be provided for the fire detection alarm systems, including all associated appurtenances, to be inspected, tested, and maintained in accordance with NFPA 72, *National Fire Alarm Code*.

4-3 Traffic Control and Surveillance.

4-3.1

For tunnel lengths greater than 300 ft (90 m), a traffic surveillance and control system should be provided. This system should be capable of monitoring and controlling traffic within and approaching the tunnel.

4-3.2

Tunnels longer than 300 ft (90 m) should provide the capability to automatically prevent approaching traffic from entering the tunnel when a fire alarm is activated. This capability should consist of traffic signals in proximity to the portal. The system should be reset to normal operation when the fire site is cleared. Control of this system can be either from within the tunnel or from a remote location.

4-3.3

Tunnels longer than 800 ft (240 m) should provide additional capabilities to divert traffic from entering the direct approaches to the tunnel and to clear traffic downstream of the fire site.

(a) Traffic beyond the direct approaches to the tunnel should be diverted by means of signs. This also could necessitate preempting traffic signals to prevent traffic from entering the approaches. This can be accomplished by omitting traffic movements or otherwise directing traffic to alternate roadways.

(b) Traffic within the tunnel approaching the fire site should be stopped prior to the fire site until it is safe to proceed. The controls used should be spaced for safe braking requirements.

Visibility requirements should be in accordance with the MUTCD.

(c) The control systems should be configured to control all modes in which the tunnel is operated.

(d) Controls should be provided so that traffic beyond the fire site can proceed to exit the tunnel. If signals are provided for this function, their display should be green.

(e) If contraflow operation is permitted during emergency vehicle response periods, the control systems should be configured to control traffic in each direction.

(f) If traffic exiting the tunnel is obstructed by intersectional traffic signals in the area of the exit, such signals should be preempted to eliminate the obstruction.

(g) The return of the traffic controls to normal operation should follow prearranged protocol between the tunnel system operator and authority having jurisdiction.

4-4 Emergency Communications.

Radio communication systems, such as highway advisory radio (HAR) and AM/FM commercial station overrides, are recommended to the motorist as communications routes for all tunnels over 800 ft (240 m) and should provide identification of the emergency and actions the motorist should take. All messaging systems for tunnels over 800 ft (240 m) should be capable of real time composition and selection by the emergency response authority and should not be of the recorded type. Areas of refuge or assembly, if available, should be provided with reliable two-way voice communication to the emergency response authority.

4-5 Emergency Response Apparatus and Equipment.

4-5.1

Emergency response apparatus should be available within the general site of the emergency, thus providing a rapid response. Where the tunnel is a high-capacity urban tunnel, it might be appropriate to house the apparatus at one or both of the tunnel portals.

4-5.2

Suitable apparatus, if appropriate, should be available at the tunnel portal(s). Apparatus should be designed for double-end lifting operation and equipped with "dollies" for towing disabled vehicles from the tunnel. The apparatus should carry a potassium bicarbonate-based dry chemical/aqueous film-forming (AFFF) or similar self-contained fire-fighting system or means to obtain water from a standpipe system, or any combination thereof. It also should carry portable extinguishers, complete self-contained breathing apparatus, cutting torches, forcible entry tools, hose, chains, coffin hoists, tarpaulins, and other appropriate hand tools. The apparatus should be equipped with a radio.

4-5.3

The responding fire apparatus should be equipped to deliver a foam solution at a minimum rate of 125 gpm (475 L/min) for a minimum duration of 15 minutes. If hydrant or standpipe water is not available, suitable arrangements should be made to transport water in tankers so that the delivery rate of foam can be maintained. Additional supplies of foam should be readily available from mutual aid fire departments or other sources so that the application can be continued for an additional 45 minutes if necessary. These units also should carry multipurpose dry chemical extinguishers and an extinguishing agent for Class D metal fires. Mutual aid, supplier, or manufacturer reserve capability should be available.

4-6 Fire Standpipe and Water Supply.

The fire standpipe and water supply are addressed in Chapter 6.

4-7 Portable Fire Extinguishers.

Portable fire extinguishers, each with at least a nominal 20-lb (9-kg) capacity for multipurpose agent, should be placed on both sides of the roadway in well-marked, flush-wall cabinets at intervals of not more than 300 ft (90 m). Portable fire extinguishers should be provided in accordance with NFPA 10, *Standard for Portable Fire Extinguishers*.

4-8 Emergency Ventilation.

Emergency ventilation is addressed in Chapter 7.

4-9 Drainage System.

4-9.1

A drainage system should be provided in tunnels to collect, store, or discharge, or any combination of these functions, influent emanating from within the tunnel. In addition to water discharged from the fire protection system and liquids from accidental spills, this influent also might include water from tunnel cleaning operations and water from incidental seepage.

4-9.2

The drainage collection system should consist of an embedded main drain pipe with grate-covered inlets regularly spaced along the curb rather than a continuous open gutter, which could allow spills of hazardous material, such as flammable liquids that could ignite, to propagate along the length of the tunnel.

4-9.3

The spacing of connections to the gravity line should be at a maximum of 100 ft (30 m) on centers.

4-9.4

Components of the drainage collection system, including the main drainlines, should be noncombustible (steel, ductile iron, or concrete). Polyvinyl chloride (PVC), fiberglass pipe, or other combustible material should not be permitted.

4-9.5

The collection system should drain to a storage tank or transfer pumping station of sufficient capacity to receive, as a minimum, the simultaneous rate of flow from two fire hoses without causing flooding on the roadway.

4-9.6

Storage tanks and pump stations should be classified for hazard in accordance with NFPA 70, *National Electrical Code*®□. All motors, starters, level controllers, and system controls should be specified to conform to the intrinsic requirements of the hazard classification.

4-9.7

Storage tanks and pump stations should be monitored for hydrocarbons. Detection of hydrocarbons in the drainage influent should initiate both a local and remote alarm.

4-10 Control of Hazardous Materials.

Control of hazardous materials is addressed in Chapter 10.

4-11 Emergency Planning.

4-11.1

It is important that a designated authority carry out a complete and coordinated program of fire protection that should include preplanned response and standard operating procedures in the form of an emergency response plan.

4-11.2

To derive the maximum benefit from the fire protection program, comprehensive training programs are necessary for all personnel and agencies expected to participate in fire-fighting operations and hazardous materials emergencies. Such a program should involve a competent supervisory staff experienced in fire-fighting techniques and hazardous materials emergencies.

4-11.3

Emergency procedures and development of emergency response plans are addressed in Chapter 9.

4-12 Alternative Fuels.

4-12.1

The majority of the vehicles currently in the U.S. traffic population are fueled by either gasoline or diesel fuel. Vehicles powered by alternative fuels have been introduced, but, at this time, the portion of the vehicle population powered by alternative fuels remains too small to impact the normal ventilation of tunnels; however, there can be an impact on the emergency ventilation. (*See Appendix F*.)

4-12.2 Mitigation Measures.

As the use of alternative fuels in road vehicles has gradually increased, each tunnel operating agency has dealt with the issue of whether to allow vehicles through the tunnels for which it is responsible. Most tunnel agencies throughout the world do allow the passage of alternative fuel vehicles.

The mitigation measures that can be taken by the tunnel designer relate primarily to the ventilation system, which, in most circumstances, can provide sufficient air to dilute the fuel below any troublesome levels adequately. It might be necessary to establish a minimum level of ventilation to provide this dilution under all circumstances. The other measure to be taken is to reduce or eliminate any irregular surfaces of the tunnel ceiling or structure where a pocket of gas could collect and remain undiluted, thus posing a potential explosive hazard.

4-13 Safeguards During Construction.

During the course of construction or major modification of any structure, the provisions of NFPA 241, *Standard for Safeguarding Construction, Alteration, and Demolition Operations*, should apply.

Exception: Where specifically addressed in this recommended practice.

4-13.1 Temporary Fire Detection and Alarm System.

A temporary fire detection and alarm system should be installed and maintained during construction. The system should consist of heat detectors; manual pull stations spaced not more than 200 ft (60 m) apart; indication appliances consisting of horn and light combination units spaced to be clearly visible/heard in all areas of construction; a fire alarm control panel; a backlighted graphic annunciator that depicts (graphically) the entire area under construction; and an approved fire alarm master box connected to the local authority having jurisdiction. All system controls and devices should be in compliance with NFPA 72, *National Fire Alarm Code*.

Chapter 5 Air Right Structures

5-1 General.

An air right structure imposes limitations on the ability of a fire fighter to fight a fire similar to those of a tunnel, due to its limited access and restricted work space.

5-2 Detection and Alarm Transmission.

5-2.1

Where the air right structure approximates the physical characteristics of a tunnel, an alarm system similar to that of a tunnel should be considered. (*See Chapter 4.*)

5-2.2 Traffic Control and Surveillance.

5-2.2.1 Where the air right structure approximates the physical characteristics of a tunnel, a traffic control and surveillance system should be considered. (*See Chapter 4.*)

5-2.2.2 A traffic control system should be provided. It may be permitted to be interlocked with the fire alarm system. The system should be capable of operation from a remote control source or from either end of the roadway passing under the air right structure. The traffic control system should be designed for use by authorized personnel only.

5-3 Fire Apparatus, Equipment.

Fire apparatus responsible for air right structure roadways are to be equipped to deal with flammable liquid and hazardous materials fires and incidents effectively. They should be equipped to carry foam, potassium-based dry chemical/aqueous film-forming foam (AFFF), or similar systems and should be suited to the unique characteristics of the structure. If the air right structure roadway approximates the physical characteristics of a tunnel, fire apparatus similar to the type used for tunnels should be used.

5-4 Fire Standpipe Systems and Water Supply Systems.

Standpipe systems for roadways within air right structures should be designed and installed as a Class I system in accordance with NFPA 14, *Standard for the Installation of Standpipe and Hose Systems*. (*See Chapter 6.*)

5-5 Portable Fire Extinguishers.

Portable multipurpose fire extinguishers, each with a minimum nominal 20-lb (9-kg) capacity, should be placed on both sides of the roadway in well-marked, flush-wall cabinets at intervals of not more than 300 ft (90 m). Consideration should be given to incorporating removal detection of an extinguisher into the alarm system.

5-6 Emergency Ventilation.

Emergency ventilation is addressed in Chapter 7.

5-7 Drainage System.

A drainage system designed in accordance with Section 4-9 should be provided for roadways beneath air right structures.

5-8 Control of Hazardous Materials.

Control of hazardous materials is addressed in Chapter 10.

5-9 Structural Factors.

5-9.1

All structural elements that support buildings over roadways or provide separation between the buildings and roadways, or both, should have a 4-hour fire resistance rating in accordance with ASTM E 119, *Standard Test Methods for Fire Tests of Building Construction and Materials*.

Exception: Buildings with a fire resistance rating greater than 4 hours.

5-9.2

Structural members should be protected from physical damage from vehicle-based accidents. An inspection and repair program should be kept in force to monitor and maintain the protection of the structure.

5-9.3

Structural support elements on centerlines of roadways should not be permitted.

5-9.4

Buildings above roadways should be designed with consideration for the fact that the roadway below the air right structure is a potential source of heat, smoke, and toxic gases. The structural elements should be designed in such a way as to shield the air right buildings from these potential hazards. The design of the building should neither increase nor create any risk to those using the roadway below.

5-10 Emergency Planning.

5-10.1

It is important that a designated authority carry out a complete and coordinated program of fire protection that includes written preplanned response and standard operating procedures.

5-10.2

To derive the maximum benefit from the fire protection program, joint comprehensive training exercises are necessary for all personnel and agencies expected to participate in fire-fighting operations and hazardous materials emergencies. The training program should involve a competent supervisory staff experienced in fire-fighting techniques and hazardous materials emergencies.

5-10.3

Emergency procedures and development of emergency response plans are addressed in

Chapter 9.

Chapter 6 Fire Standpipe and Water Supply

6-1 Standpipe Systems.

6-1.1

Standpipe systems for tunnels, bridges, and elevated and limited access roadways should be designed and installed as Class I systems in accordance with NFPA 14, *Standard for the Installation of Standpipe and Hose Systems*.

6-1.2

Standpipe systems should be permitted to be either wet or dry, depending upon climatic conditions, fill times, or the requirements of the authority having jurisdiction, or any combination thereof.

6-1.3

Where wet standpipe systems are required in areas subject to freezing conditions, the water should be heated and circulated, and all piping and fittings exposed to such conditions should be heat-traced and insulated.

6-1.4

Wet standpipe systems should be provided with suitable interconnection and bypass valve arrangements to allow isolation and repair of any segment without impairment to the operation of the remainder of the system.

6-1.5

Dry standpipe systems should be designed to ensure that the delivery time of water to any hose connection on the system is less than 10 minutes. Dry standpipe systems should have provisions for complete draining after use. Combination air relief/vacuum valves should be installed at each high point on the system.

6-1.6

Dry standpipes should be installed in a manner that provides accessibility for inspection and repair and should be protected from damage by moving vehicles.

6-2 Design Capacity.

6-2.1

Standpipe systems should be designed to provide a minimum water supply of 250 gpm (16 L/s) at 100 psi (690 kPa) residual at the most remote hose connection with a minimum of two hose connections flowing for a total flow of 500 gpm (32 L/s) at 65 psi (450 kPa) residual.

6-2.2

Maximum residual pressure at any hose connection should be limited to 175 psi (1207 kPa) by means of an approved pressure regulating device.

6-3 Water Supply.

6-3.1

Wet standpipe systems (automatic or semiautomatic) should be connected to an approved water supply capable of supplying the system demand for a minimum of 1 hour.

6-3.2

Dry standpipe systems should have an approved water supply capable of supplying the system demand for a minimum of 1 hour and accessible to a fire department pumper within 100 ft (30 m) of each fire department connection.

6-3.3

Acceptable water supplies include the following:

(a) Municipal or privately owned waterworks systems having adequate pressure and flow rate and a level of integrity acceptable to the authority having jurisdiction;

(b) Automatic or manually controlled fire pumps connected to an approved water source;

(c) Pressure-type or gravity-type storage tanks installed in accordance with NFPA 22, *Standard for Water Tanks for Private Fire Protection*.

6-4 Fire Department Connections.

6-4.1

Fire department connections should be of the threaded two-way or three-way type or should consist of one 4-in. quick-connect coupling located at ground surface level and accessible to a fire department pumper.

6-4.2

Each standpipe zone should have a minimum of two fire department connections located remotely from each other.

6-4.3

Fire department connections should be protected from vehicular damage by means of bollards or other suitable barriers.

6-4.4

Wherever possible, fire department connection locations should be coordinated with emergency access/egress locations.

6-5 Hose Connections.

6-5.1

Hose connections should be spaced so that no location on the protected roadway is more than 150 ft (45 m) from the hose connection. Hose connection spacing should not exceed 275 ft (85 m). Hose connections should be located so that they are conspicuous and convenient yet reasonably protected from damage by errant vehicles or vandals.

6-5.2

Hose connections should have $2^1/_2$-in. (63.5-mm) external threads in conformance with NFPA 1963, *Standard for Fire Hose Connections*, and the authority having jurisdiction. Hose connections should be equipped with caps to protect hose threads.

6-6 Fire Pumps.

Fire pumps should be supplied as necessary and should be installed in accordance with NFPA 20, *Standard for the Installation of Centrifugal Fire Pumps*.

6-7 Identification Signage.

6-7.1

Identification signage for standpipe systems and components should be developed with input from the authority having jurisdiction. Identification signage should, as a minimum, identify the name and limits of the roadway served.

6-7.2

Identification signage should be conspicuous and affixed to, or immediately adjacent to, ground surface level fire department connections and each roadway hose connection.

6-8 Standpipe Installation in Tunnels Under Construction.

6-8.1

A standpipe system, either temporary or permanent in nature, should be installed in tunnels under construction before the tunnel has exceeded a length of 200 ft (60 m) beyond any access shaft and should be extended as tunnel work progresses.

6-8.2

Temporary standpipes, which can be used by contractors to furnish water for construction purposes, should be equipped with hose outlets and valves with $2^{1}/_{2}$-in. (63.5-mm) hose thread conforming to NFPA 1963, *Standard for Fire Hose Connections*, and can have suitable reducers or adapters attached for connection of contractor's hose. Such reducers or adapters should be readily removable using the fire fighter's hose spanner wrenches.

6-8.3

Permanent standpipes or temporary standpipes installed in tunnels during construction should be provided with risers to approved fire department connections at ground surface level.

6-8.4

Permanent or temporary standpipes installed during the construction phase should be supported securely and adequately and should be of sufficient strength to withstand the pressure and thrust forces to which they are subjected.

6-8.5

Temporary standpipes should remain in service until the permanent standpipe installation is complete.

Chapter 7 Emergency Tunnel Ventilation

7-1 General.

Ventilation systems and procedures should be developed to allow maximum utilization of the tunnel ventilation system for the removal and control of smoke during fires. The ventilation equipment should be heat resistant so it is capable of operating even under sustained fire exposure temperatures. The design of the ventilation system should provide for excess ventilation to accomplish this purpose. The ventilation procedures should be designed to assist in the evacuation of motorists from the tunnel.

7-2 Design.

The design objectives of the emergency ventilation system should be as follows:

(a) To provide a stream of noncontaminated air to passengers in a path of egress away from a fire (*see Appendix C*);

(b) To produce airflow rates to prevent backlayering of smoke in a path of egress away from a fire;

(c) To limit the air temperature in a path of egress away from fire to 140ÿF (60ÿC) or less;

(d) To provide excess ventilation capabilities to achieve the temperature limitation specified in Section 7-2(c);

(e) To prevent or minimize adverse effects on air right structures and their occupants from fire products such as heat, smoke, and toxic gases.

7-3 Memorial Tunnel Fire Ventilation Test Program.

The Memorial Tunnel Fire Ventilation Test Program is a full-scale test program conducted under the auspices of the United States Federal Highway Administration (FHWA) to evaluate the effectiveness of various tunnel ventilation systems and ventilation airflow rates to control the smoke from a fire. The results of this program can have an impact on the design criteria for highway tunnel emergency ventilation. (*See Appendix G.*)

7-4 Criteria.

The design heat release rate produced by a vehicle should be used to design the emergency ventilation system.

7-5 Fans.

Ventilation fans used for emergency service, their motors, and all related components exposed to the ventilation airflow should be designed to operate in an ambient atmosphere of 482°F (250°C) for at least 1 hour.

7-5.1

Fans should be fixed or variable speed type driven by single speed, multiple fixed speed, or variable frequency drive motors. They should be permitted to be reversible and should be both locally and remotely controlled, as approved. They should be connected to two power feeders derived from two separate sources. Power feeders from a utility furnishing power for fans should be isolated from each other and should originate from separate and distinct utility sources to the extent possible.

7-5.2

Remote control operation of the tunnel ventilation fans at an approved location accessible to authorized fire and emergency personnel should be provided.

7-5.3

Local fan motor starters and related operating control devices should be located away from the direct airstream of the fans to the greatest extent practical.

7-5.4

Discharge/outlet openings for emergency fans should be positioned a sufficient distance from supply air intake openings to prevent recirculation. If this is not possible due to area constraints, intake openings then should be protected by other approved means or devices to prevent smoke from reentering the system.

7-5.5

Operation and fail-safe verification of proper operation of emergency fans should be effected from a remote location with indication provided for all modes of operation for each fan, as well as from a local control isolated from the direct airstream of the fans. Thermal overload protective devices should not be located on motor controls of fans dedicated solely to emergency ventilation. Local controls should allow overriding of the remote control. Local control should be capable of operating the fans in all modes in the event the remote controls become inoperable.

7-6 Controls — Fire Detection and Alarm System Operation.

A fire-fighter fan control override control station should be provided to give full control of the running speed of all tunnel fans to the local authority having jurisdiction. The location and marking of the fan override control station should be determined by the authority having jurisdiction.

Chapter 8 Electrical Systems

8-1 General.

8-1.1

The electrical systems should support personnel life safety, emergency operations, and normal operations.

8-1.2

The systems should maintain illumination, communications, and ventilation, identify areas of refuge/exit and exit routes, and provide remote annunciation/alarm and drainage under all operating and emergency modes associated with the roadway.

8-2 Wiring.

All wiring materials and installation should conform to NFPA 70, *National Electrical Code*, as modified in this recommended practice.

8-3 Materials.

8-3.1

Materials manufactured for use as conduits, raceways, ducts, cabinets, and equipment enclosures and their surface finish materials, as installed, should be capable of being subjected to temperatures up to 600°F (316°C) for 1 hour and should not support combustion under the same temperature condition.

8-3.2

The systems should not use materials within the confined spaces of limited access roadways that produce toxic by-products during electric circuit failure or when subjected to an external fire. PVC conduit and vinyl- (PVC) insulated/jacketed conductors or cables should not be used in tunnels, plenums, or enclosed spaces.

8-3.3

All insulations should conform to NFPA 70, *National Electrical Code*, and should be of the moisture- and heat-resistant types with temperature ratings corresponding to the conditions of application.

8-3.4

All conductors should be completely enclosed in armor sheaths, conduits, or enclosed raceways, boxes, and cabinets. Conductors in a raceway can be embedded in concrete or run in protected electrical duct banks, but they should not be installed in an exposed manner or surface mounted in air plenums that could carry air at the elevated temperatures accompanying fire emergency conditions.

8-4 Power Source.

The power source for all systems should be of a capacity and configuration commensurate with the purpose of the system. The following systems should be provided with emergency power:

(a) Emergency lighting;

(b) Means of egress/refuge lighting;

(c) Exit signs;

(d) Communications as defined herein;

(e) Tunnel drainage and fire pump(s).

Consideration should be given to providing emergency power to support ventilation of tunnels where such tunnels are needed to support the passage of vehicles during loss of normal power.

The recommendations for emergency sources should be as defined in NFPA 70, *National Electrical Code*. In addition, the normal and emergency source should be wired to system equipment so that a single event or fire minimizes the affect on the operation of the overall system. (It is expected that the operations of all systems within the vicinity of a fire will fail. This provision is intended to limit the area of this failure.)

8-5 Reliability.

The primary source of electric service should be from the local electric utility.

Exception: A separate service may be permitted to be an emergency source, provided it can be demonstrated that a single event within the utility system cannot affect both the primary and emergency source.

8-6 Standby System.

It should be recognized that normal service within the utility system affects one source at a time. It is not the intent of the emergency recommendation to address an event within the roadway while one source is not available. However, an additional source supporting select systems can be permitted to be provided near the roadway system to maintain operations.

8-7 Lighting.

8-7.1

Roadway illumination should meet the requirements of ANSI/IES RP-8, *American National Standard Practice for Roadway Lighting*, and ANSI/IES RP-22, *American National Standard Practice for Tunnel Lighting*. In addition, means of egress, exits, and emergency lighting should be in accordance with NFPA *101*®, *Life Safety Code*®. Emergency tunnel lighting illumination levels should not be less than 0.2 footcandles [0.22 lux] (minimum average) throughout personnel egress paths.

8-7.2

There are several issues that are related to the available equipment and features of a limited access roadway. The most significant is the emergency response agency(ies). In rural areas where response units are often made up of volunteers, longer response times can be expected. Under these conditions, self-rescue should be considered. Lighting of special features (such as fire pull stations, extinguishers, and telephones) and special feature instructional signage should be provided with emergency lighting.

8-8 Life Safety During Construction.

The construction or renovation of a tunnel or other below grade roadway should include the basic worker safety provisions of OSHA 29 *Code of Federal Regulations*, 1910S, "Underground Construction, Caisson, and Compressed Air," and OSHA 29 *Code of Federal Regulations*, 1910S, "Electrical, Safety-Related Work Practices." In addition, systems should be installed that support the construction operations in a safe manner. The method of lighting, heating, ventilation, and drainage should support the expected number of construction personnel and consider the equipment, the task, and the duration of the work. The primary underground power source should be electric. Electric power distribution should be configured so that system failure or an emergency condition allows for the safe evacuation of the facility.

Chapter 9 Emergency Procedures

9-1 General.

The agency that is responsible for the safe and efficient operation of the facility should anticipate and plan for emergencies that could involve the system. Participating agencies should be invited and should assist with the preparation of the emergency procedure plan.

9-2 Emergencies.

The following types of emergencies should be considered cause for invoking the emergency procedure plan:

(a) Fire or a smoke condition in a vehicle or in the facility;

(b) Fire or a smoke condition adjoining or adjacent to the facility;

(c) Collision involving one or more vehicles;

(d) Loss of electric power resulting in loss of illumination and ventilation;

(e) Evacuation of motorists from vehicles under adverse conditions where they need assistance;

(f) Panic of motorists;

(g) Disabled vehicles under adverse conditions;

(h) Serious flooding condition due to water main break, heavy rain, poor drainage, loss of electric power, or failure of pumping equipment;

(i) Structural collapse or imminent collapse that threatens safety;

(j) Seepage and spillage of petroleum products or flammable, toxic, or irritating vapors;

(k) Serious vandalism or other criminal acts, such as a bomb threat;

(l) First aid or medical attention needed by motorists;

(m) Extreme weather conditions, such as heavy snow, rain, high winds, high heat, low temperatures, or sleet and ice conditions, causing disruption of operation;

(n) Earthquake.

9-3 Emergency Response Plan.

9-3.1

The emergency response plan should include, but should not be limited to, the following:

(a) Name of plan;

(b) Name of responsible agency;

(c) Dates adopted, reviewed, and revised;

(d) Policy, purpose, scope, and definitions;

(e) Participating agencies, top officials, and signatures of executives signing for each agency;

(f) Safety during emergency operations;

(g) Purpose and operation of central supervising station and alternate central supervising station;

(h) Purpose and operation of command post and auxiliary command post;

(i) Communications: radio, telephone, and messenger service available at central supervising station and command post; also, efficient operation of these facilities;

(j) Fire detection, fire protection, fire extinguishing equipment, and access/egress and ventilation facilities available; details of the type, amount, location, and method of utilization;

(k) Procedures for fire emergencies; various types of fire emergencies, agency in command, and procedures to follow;

(l) Maps and plans of the roadway system and of all surface and connecting streets;

(m) Any additional information and data that the participating agencies desire to have in the plan.

9-3.2

A sample emergency response plan outline is provided in Appendix E.

9-4 Participating Agencies.

Participating agencies that should be summoned by operators to cooperate and assist, depending upon the nature of an emergency, include:

(a) Ambulance service;

(b) Building department;

(c) Fire department;

(d) Medical service;

(e) Police department;

(f) Public works, bridges, streets, sewers;

(g) Sanitation department;

(h) Utility companies (e.g., gas, electricity, telephone, steam);

(i) Water supply;

(j) Local transportation companies.

The agencies and names will vary depending upon the governmental structure and laws of the community.

9-5 Central Supervising Station.

If the facility has a central supervising station (CSS) for the operation and supervision of the facility, 9-5.1 through 9-5.7 should apply.

9-5.1

The CSS should be staffed by trained and qualified personnel and should be provided with the essential apparatus and equipment to communicate with, supervise, and coordinate all personnel.

9-5.2

The CSS should provide the capability to communicate rapidly with participating agencies. Agencies such as fire, police, ambulance, and medical service should have direct telephone lines or designated telephone numbers used for emergencies involving the facility.

9-5.3

Equipment should be available and used for recording radio and telephone communications and CCTV transmissions during an emergency.

9-5.4

CSS personnel should be thoroughly familiar with the emergency procedure plan and trained to employ it effectively.

9-5.5

An alternate site(s) that can function efficiently during an emergency in the event the CSS is out of service for any reason should be selected and equipped, or equipment should be readily available.

9-5.6

The CSS should be located in an area separated from other occupancies by construction having a 2-hour fire resistance rating. The area should be used for the CSS and similar activities and should not be jeopardized by adjoining or adjacent occupancies.

9-5.7

The CSS should be protected by fire detection, protection, and extinguishing equipment to provide early detection and extinguishment of any fire in the CSS.

9-6 Liaison.

9-6.1

An up-to-date list of all liaison personnel from participating agencies should be maintained by the operating agency and should be part of the emergency procedure plan.

The list should include the full name, title, agency, business telephone number(s), and home telephone number of the primary liaison as well as an alternate.

9-6.2

The list should be reviewed at least once every 3 months to verify the ability to contact the liaison without delay.

9-7 Command Post.

9-7.1

During an emergency where it is necessary to invoke the emergency procedure plan, a command post should be established by the person in command for the supervision and coordination of all personnel, equipment, and resources at the scene of the emergency.

9-7.2

The emergency procedure plan should delineate clearly the authority or participating agency that is in command and responsible for supervision, correction, or alleviation of the emergency.

9-7.3

The command post should be located at a site convenient for responding personnel, easily identifiable, and suitable for supervising, coordinating, and communicating with participating agencies.

9-7.4

Each participating agency should assign a liaison to the command post.

9-7.5

Effective use should be made of radio, telephone, and messenger service to communicate with participating agencies.

9-7.6

To identify the command post easily during day or night and under bad weather conditions, designated markers should be employed. The emergency procedure plan should prescribe the specific identification markers to be used for the command post and its assigned personnel.

9-8 Auxiliary Command Post.

9-8.1

Where it is necessary for an emergency operation to use an auxiliary command post because of the extent of the operation, the person in command should establish an auxiliary command post(s) that can function as a subordinate control point.

9-8.2

Where authorized, a participating agency (not in command) should establish an auxiliary command post to assist with the supervision and coordination of its personnel and equipment.

9-9 Training, Exercises, Drills, and Critiques.

9-9.1

Operating agency and participating agency personnel should be trained to function efficiently during an emergency. They should be thoroughly familiar with all aspects of the emergency procedure plan.

9-9.2

Exercises and drills should be conducted at least twice per year to prepare the authority and participating agency personnel for emergencies. Critiques should be held after the exercises, drills, and actual emergencies.

9-10 Records.

Written records and telephone, radio, and CCTV recordings should be kept at the CSS, and written records should be kept at the command post and auxiliary command post(s) during fire emergencies, exercises, and drills.

Chapter 10 Control of Hazardous Materials

10-1 General.

The facility operating agency should adopt rules and regulations applicable to the transportation of hazardous materials. A program should be maintained for enforcing these regulations. In developing such regulations, consideration should be given to the following:

(a) The availability of a suitable alternative route(s) meeting federal requirements as prescribed in Title 49, *Code of Federal Regulations*, 177.825, "Routing and Training Requirements for Class 7 (Radioactive) Materials," and Title 49, *Code of Federal Regulations*, Part 397, Subpart C, "Routing of Non-Radioactive Hazardous Materials."

(b) Title 49, Department of Transportation, *Code of Federal Regulations*, Subtitle B, Parts 100 to 199;

(c) The fire and accident experience of other similar facilities;

(d) Past fire and accident experience on the facility and adjacent roads, or, in the case of a new facility, the past fire and accident experience on roads in the area;

(e) Anticipated traffic volumes in peak and off-peak periods;

(f) The need for inspection of vehicles and cargo and the availability of a safe place to conduct inspections with a minimum of traffic interference;

(g) The need and desirability of escort service with due consideration of the extent to which it could disrupt the orderly flow of traffic and create additional hazards;

(h) A plan developed by an operating agency in a dense urban area is referenced in Appendix H. This might not be suitable for all such facilities.

Chapter 11 Referenced Publications

11-1

The following documents or portions thereof are referenced within this recommended practice and should be considered part of the recommendations of this document. The edition indicated for each reference is the current edition as of the date of the NFPA issuance of this document.

11-1.1 NFPA Publications.

National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.

NFPA 10, *Standard for Portable Fire Extinguishers*, 1994 edition.

NFPA 14, *Standard for the Installation of Standpipe and Hose Systems*, 1996 edition.

NFPA 20, *Standard for the Installation of Centrifugal Fire Pumps*, 1996 edition.

NFPA 22, *Standard for Water Tanks for Private Fire Protection*, 1996 edition.

NFPA 30, *Flammable and Combustible Liquids Code*, 1996 edition.

NFPA 30A, *Automotive and Marine Service Station Code*, 1996 edition.

NFPA 70, *National Electrical Code*, 1996 edition.

NFPA 72, *National Fire Alarm Code*, 1996 edition.

NFPA *101*, *Life Safety Code*, 1994 edition.

NFPA 241, *Standard for Safeguarding Construction, Alteration, and Demolition Operations*, 1996 edition.

NFPA 1963, *Standard for Fire Hose Connections*, 1993 edition.

11-1.2 Other Publications.

11-1.2.1 ASHRAE Publication. American Society of Heating, Refrigerating and Air Conditioning Engineers, Inc., 1725 Tullie Circle, Atlanta, GA 30329.

ASHRAE *Handbook — Applications*, 1995 edition.

11-1.2.2 ASTM Publications. American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103.

ASTM E 119, *Standard Test Methods for Fire Tests of Building Construction and Materials*, A-1995.

ASTM E 136, *Standard Test Method for Behavior of Materials in a Vertical Tube Furnace at 750 Degrees C*, A-1994.

11-1.2.3 IES Publications. Illuminating Engineering Society, 345 East 47th Street, New York, NY 10017.

ANSI/IES RP-8, *American National Standard Practice for Roadway Lighting*, 1983.

ANSI/IES RP-22, *American National Standard Practice for Tunnel Lighting*, 1987.

11-1.2.4 U.S. Government Publications. Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20401.

Title 29, *Code of Federal Regulations*, Subtitle B, Chapter XVII, Part 1910, Subpart S, "Underground Construction, Caissons, and Compressed Air," 1994.

Title 29, *Code of Federal Regulations*, Subtitle B, Chapter XVII, Part 1910, Subpart S, "Electrical," 1994.

Title 49, Department of Transportation, *Code of Federal Regulations*, 177.810, "Vehicle Tunnels."

Title 49, Department of Transportation, *Code of Federal Regulations*, 177.825, "Routing and Training Requirements for Class 7 (Radioactive) Materials."

Title 49, Department of Transportation, *Code of Federal Regulations*, Part 397, Subpart C, "Routing of Non-Radioactive Hazardous Materials."

Title 49, Department of Transportation, *Code of Federal Regulations*, Part 397, Subpart D, "Routing of Class 7 (Radioactive) Materials."

Title 49, Department of Transportation, *Code of Federal Regulations*, Part 397, Subpart E, "Preemption Procedures."

Title 49, Department of Transportation, *Code of Federal Regulations*, Subtitle B, Parts 100 to 199.

"Guidelines for Applying Criteria to Designate Routes for Transporting Hazardous Materials," DOT/RSPA/OHMT-89-02-1989.

"Guidelines for Selecting Preferred Highway Routes for Highway Route-Controlled Quantity Shipments of Radioactive Materials."

US DOT, Federal Highway Administration, Pub # FHWA-SA-94-083. Available through National Technology, September 1, 1994. Information Service, Springfield, VA 21661

11-1.2.5 MUTCD. *Manual on Uniform Traffic Control Devices for Streets and Highways*.

Appendix A Explanatory Material

This Appendix is not a part of the recommendations of this NFPA document but is included for informational purposes only.

A-1-12.1 See ASTM E 380, *Standard Practice for Use of the International System of Units (SI) (the Modernized Metric System)*, and ANSI/IEEE 268, *American National Standard for Metric Practice*.

A-1-13 Approved. The National Fire Protection Association does not approve, inspect, or certify any installations, procedures, equipment, or materials; nor does it approve or evaluate testing laboratories. In determining the acceptability of installations, procedures, equipment, or materials, the authority having jurisdiction may base acceptance on compliance with NFPA or other appropriate standards. In the absence of such standards, said authority may require evidence of proper installation, procedure, or use. The authority having jurisdiction may also refer to the listings or labeling practices of an organization concerned with product evaluations that is in a position to determine compliance with appropriate standards for the current production of listed items.

A-1-13 Authority Having Jurisdiction. The phrase "authority having jurisdiction" is used in NFPA documents in a broad manner, since jurisdictions and approval agencies vary, as do their responsibilities. Where public safety is primary, the authority having jurisdiction may be a federal, state, local, or other regional department or individual such as a fire chief; fire marshal; chief of a fire prevention bureau, labor department, or health department; building official; electrical inspector; or others having statutory authority. For insurance purposes, an insurance inspection department, rating bureau, or other insurance company representative may be the authority having jurisdiction. In many circumstances, the property owner or his or her designated agent assumes the role of the authority having jurisdiction; at government installations, the commanding officer or departmental official may be the authority having jurisdiction.

A-1-13 Listed. The means for identifying listed equipment may vary for each organization concerned with product evaluation, some of which do not recognize equipment as listed unless it is also labeled. The authority having jurisdiction should utilize the system employed by the listing organization to identify a listed product.

A-1-13 Point of Safety. The egress population to be served should be determined by engineering analysis.

A-2-4.2 Such procedures have the dual purpose of preventing the involvement of additional vehicles in the original accident and of slowing traffic during inclement weather conditions.

Appendix B Air Quality Criteria in Emergencies

This Appendix is not a part of the recommendations of this NFPA document but is included for informational purposes only.

B-1 General.

B-1.1 In this appendix, criteria for the protection of the motorist, employee, and fire fighter during emergency situations are provided with regard to air quality, temperatures, and velocities.

B-1.2 To a large extent, the quantitative aspects of the criteria for emergency situations is arbitrary because there are no universally accepted tolerance limits pertaining to air quality, temperatures, and velocities. In fact, tolerance limits vary with age, health, weight, sex, and acclimatization. Most of the studies on human tolerance to adverse situations have dealt with exposure tests on healthy, acclimated adults. These individuals can survive in environments potentially harmful to the less physically fit. Criteria should instead be established based on the tolerances of higher risk groups: infants, the aged, and those suffering from respiratory or cardiac ailments. Little information is available on the physiological tolerance limits of people with health impediments, especially for short-term but intense exposures.

B-2 Emergency Air Quality Criteria.

B-2.1 During tunnel emergencies involving fire or generation of smoke, the products of combustion produce gases and aerosols, some of which are potentially toxic or incapacitating. The aerosols in smoke also tend to limit visibility. In the event of fire, the intended purpose of all emergency ventilation equipment, therefore, is to provide control of smoke migration and an effective means to purge smoke and supply fresh air to motorists and fire department personnel during evacuation and early fire-fighting operations.

B-2.2 Since some emergency situations could conceivably occur where all motorists cannot be provided with fresh air for the entire length of an evacuation route, criteria are needed to maintain air quality for those passengers. Such a situation would exist, for example, where two fire incidents have occurred in a tunnel. Because fresh air might come from only one direction, motorists positioned between the incidents could be exposed to air containing some combustion products, while motorists located in areas beyond either incident receive fresh air. Sufficient fresh air, however, needs to be supplied to motorists downwind of a fire to dilute adequately any harmful combustion product.

B-2.2.1 The usual way in which potentially harmful gases or aerosols enter the human body is through the respiratory tract. The physiological reactions of a person depend on the contaminant and its concentration and exposure time and will vary for each person. A person's reaction to potentially harmful combustion products is proportional to a characteristic of the environment that is quantified by the concentration-time product, CT.

B-2.2.2 During design, the ventilation engineer does not know how much of the smoke and combustion products will be made airborne or the exposure time of passengers in the smoke. These quantities depend on the nature of the emergency, the construction materials, and the tunnel's overall emergency policies. Nevertheless, emergency ventilation systems need to be sized, and some guidance is provided by approximating the concentration-time product, CT, for different airflow rates. (*See Subway Environmental Design Handbook, Vol. I, Principles and Applications.*)

B-3 Emergency Air Temperature Criteria.

B-3.1 It is anticipated that the 140°F (60°C) air temperature will place a physiological burden on a few motorists, but the exposure also is anticipated to be brief and to produce no lasting harmful effects. Motorists should not be exposed to maximum air temperatures exceeding 140°F (60°C) during emergencies. The heat released from a fire depends on the type and amount of material burning as well as the rate at which it burns. In a tunnel, the materials capable of supporting combustion are engine fuel, plastics, oil, wood, paper, cardboard, and bituminous products.

B-3.2 Studies of the severity of tunnel fires with respect to human environmental criteria demonstrate that the air temperature in the absence of toxic smoke is a limiting criterion for human survival.

B-4 Emergency Air Velocity Criteria. The purpose of ventilation equipment in a tunnel emergency is to sweep out heated air and to remove the smoke caused by any fire. In essentially all emergency cases, protection of the motorists and employees is enhanced by prompt activation of emergency ventilation procedures as planned in advance.

B-4.1 When emergency ventilation air is needed in evacuation routes, it might be necessary to expose passengers to air velocities higher than those permitted by normal nuisance considerations. The only upper limit to the ventilation rate occurs when the air velocity becomes great enough to create a hazard to persons walking in that airstream. According to the descriptions of the effects of various air velocities given in the Beaufort scale, motorists under emergency conditions can tolerate as much as 2200 ft/min (11 m/s).

B-4.2 The minimum air velocity within the tunnel section experiencing the fire emergency should be sufficient to mitigate backlayering of the smoke (i.e., a flow of smoke in the upper cross section of the tunnel that is opposite in direction to the forced ventilation air).

B-4.3 Increasing the airflow rate in the tunnel decreases the airborne concentration of potentially harmful chemical compounds (referred to hereinafter by the general term "smoke"). The decrease in concentration is beneficial to those exposed to the compounds. However, a situation could arise in which the smoke source is completely removed and poses no threat of exposure to passengers, and actuating any fans would draw the smoke to the evacuation routes. Under these conditions, the fans should not be activated until it is safe to do so. To make decisions under these circumstances, a rapid and thorough communication system is needed so that the responsible personnel can make judgments based on information available that are consistent with established emergency policies.

B-4.4 The effectiveness of an emergency ventilation system in providing a sufficient quantity of noncontaminated air and in minimizing the hazard of smoke backlayering in an evacuation pathway is a function of the fire load. The fire load in a tunnel results from the burning rate of a vehicle(s), which, in turn, is a function of the combustible load in Btu of the vehicle.

Appendix C Critical Velocity Calculations

This Appendix is not a part of the recommendations of this NFPA document but is included for informational purposes only.

The simultaneous solution of equations C-1 and C-2, by iteration, determines the critical velocity. The critical velocity is the minimum steady-state velocity of the ventilation air moving toward the fire that is necessary to prevent backlayering:

$$V_c = K_1 K_g \left(\frac{gHQ}{\rho C_p A T_f} \right)^{1/3} \quad \text{(C-1)}$$

$$T_f = \left(\frac{Q}{\rho C_p A V_c} \right) + T \qquad \text{(C-2)}$$

where:

A = Area perpendicular to the flow [ft^2 (m^2)].

C_p = The specific heat of air [Btu/lb R (kJ/kg K)].

g = The acceleration caused by gravity [ft/sec-sec (m/s-s)].

H = The height of the duct or tunnel at the fire site [ft (m)].

K_1 = 0.606.

K_g = Grade factor (see chart below).

Q = The heat the fire is adding directly to the air at the fire site [Btu/hr (MW)].

T = The temperature of the approach air [°F (°C)].

T_f = The average temperature of the fire site gases [°F (°C)].

V_c = Critical velocity [ft/min (m/s)].

ρ = The average density of the approach (upstream) air [lb/ft^3 (kg/m^3)].

$$V_c = K_1 K_g \left(\frac{gHQ}{\rho C_p A T_f} \right)^{1/3} \qquad \text{(C-1)}$$

Figure C-1 Grade factor for determining critical velocity.

Appendix D Fire Sprinklers in Highway Tunnels

This Appendix is not a part of the recommendations of this NFPA document but is included for informational purposes only.

D-1 General. This appendix provides design considerations for fire sprinklers in road tunnels.

D-1.1 Currently, the use of and effectiveness of fire sprinklers in vehicular roadway tunnels is not universally accepted. Although it is acknowledged that sprinklers are highly regarded by fire protection professionals and fire departments in certain types of structures, there is much evidence to suggest that sprinklers are not only ineffective in controlling a fuel fire but can actually contribute to the spread or severity of the fire. Furthermore, it is felt that vehicular tunnel conditions cannot exploit sprinkler system strengths and could turn most of their advantages into disadvantages.

D-1.2 The major concerns expressed by tunnel authorities regarding fire sprinkler use and effectiveness include the following:

(a) Typical fires usually occur under vehicles or inside passenger or engine compartments designed to be waterproof from above; therefore, overhead sprinklers would have no extinguishing effect.

(b) A thin water spray on a very hot fire, if any delay occurs between ignition and sprinkler activation, will produce large quantities of superheated steam without materially suppressing the fire. This steam has the potential to be more damaging than smoke.

(c) Tunnels are very long and narrow, often sloped laterally and longitudinally, vigorously ventilated, and never subdivided, so heat normally will not be localized over a fire.

(d) Because of stratification of the hot gases plume along the tunnel ceiling, a number of the activated sprinklers would not, in all probability, be located over the fire. A large number of the activated sprinklers would be located away from the fire scene, producing a cooling effect that would tend to draw this stratified layer of smoke down toward the roadway level.

(e) Even a light spray from sprinklers would catch motorists unaware and would be in excess of that which windshield wipers could clear (even if they were on), possibly causing the roadway to become dangerously slippery.

(f) Water squirting from the ceiling of a subaqueous tunnel could suggest tunnel failure and induce panic in motorists.

(g) The use of sprinklers could cause the delamination of the smoke layer and induce turbulence and mixing of the air and smoke, thus threatening the safety of persons in the tunnel.

(h) Testing of a fire sprinkler system on a periodic basis to determine its state of readiness is impractical and costly.

D-1.3 Because of the concerns detailed in D-1.2, the use of sprinklers in highway tunnels generally is not recommended. However, three recently commissioned U.S. vehicular tunnels have been equipped with sprinkler systems: the Central Artery North Area (CANA) Route 1 tunnels in Boston, MA, and the I-90 First Hill Mercer Island and Mt. Baker Ridge tunnels in Seattle, WA. The decision to provide sprinklers in these tunnels was motivated solely by the fact that these tunnels will be operated to allow the unescorted passage of vehicles carrying/hauling hazardous cargo.

D-2 Application. The installation of sprinkler systems should be considered applicable only where the passage of hazardous cargo is considered. However, even in these cases, the tunnel operator and the local fire department or authority having jurisdiction should consider the advantages and disadvantages of such systems as they apply to a particular tunnel installation.

D-3 Extinguishing Agent. AFFF (aqueous film-forming foam) systems should be considered for in-tunnel sprinkler systems in lieu of water-only systems. Water-only sprinkler systems pose significant concerns where applied to roadway tunnels. The high water demand rate needs to be available from the local supply, and in-tunnel drainage piping, storage, and pumping systems all become much larger. Additionally, after deluge, the possibility of vapor explosion is dangerously increased. The strong cooling effect of a water-only system reduces the ability of the smoke to stratify at the ceiling, where it can be contained more easily by the tunnel ventilation system, and instead causes the smoke to spread over the cross section of the incident area.

D-4 Sprinkler System. To help ensure against accidental discharge, the sprinkler system should be designed as a manually activated deluge system. The sprinkler system piping should be arranged using interval zoning so that the discharge can be focused on the area of incident without necessitating discharge for the entire length of the tunnel. Each zone should be equipped with its own proportioning valve set to control the appropriate water/foam mixture percentage. Sprinkler heads should provide an open deluge and be spaced so that coverage extends to roadway shoulders and, if applicable, maintenance/patrol walkways. The system should be designed with enough water and foam capacity to allow operation of at least two zones adjacent to the incident zone if the fire occurs in a "border" area. Zone length should be based on activation time as determined by the authorities having jurisdiction. Piping should be designed to allow drainage through heads after flow is stopped.

D-5 System Control. It can be assumed that a full-time, attended control room is available for any tunnel facility in which safe passage necessitates the need for sprinkler system protection. Therefore, consideration should be given to human interaction in the sprinkler system control and activation design to ensure against false alarm and accidental discharge. Any automatic mode of operation should include a discharge delay to allow incident verification and assessment of in-tunnel conditions by trained operators.

An integrated graphic display of the sprinkler system zones, fire detection system zones, tunnel ventilation system limits, and emergency access and egress locations should be provided at the control room to allow tunnel operators and responding emergency personnel to make initial response decisions.

Appendix E Emergency Response Plan Outline

This Appendix is not a part of the recommendations of this NFPA document but is included for informational purposes only.

E-1 General.

E-1.1 Purpose.

E-1.2 Background.

E-2 Emergency Response Plan.

E-2.1 General.

E-2.2 Elements of the Plan.

E-2.2.1 Central Supervising Station (CSS).

E-2.2.2 Alternate CSS.

E-2.2.3 Incident/Activity Identification Systems.

E-2.2.4 Emergency Command Posts.

E-2.3 Operational Considerations.

E-2.4 Types of Incidents.

E-2.5 Possible Locations of Incidents.

E-2.6 Incidents on Approach Roadways.

E-2.7 Incidents within Tunnel or Facility.

E-3 Coordination with Other Responsible Agencies.

E-3.1 Fire Fighting Operational Procedures.

E-3.2 Traffic Management.

E-3.3 Medical Evacuation Plan.

E-3.4 Emergency Alert Notification Plan.

Appendix F Alternative Fuels

This Appendix is not a part of the recommendations of this NFPA document but is included for informational purposes only.

F-1 General. Most vehicles currently in the traffic population are powered by either spark-ignited or compression-ignited engines. Vehicles that use alternative fuels such as CNG, LPG, and LNG are being introduced into the vehicle population, but their percentage of the population is still too low for their characteristics to be a significant influence in the design of highway tunnel ventilation with regard to vehicle emissions. However, growing concerns regarding the safety of some of these vehicles operating within tunnels might soon affect the fire-related life safety design aspects of highway tunnels.

It is evident that there will be continued growth in the use of vehicles powered by alternative fuels (i.e., fuels other than gasoline or diesel). Of these potential alternative fuels, liquefied petroleum gas (LPG) currently is the most widely used, although the use of both compressed natural gas (CNG) and liquefied natural gas (LNG) are growing. The American Gas Association estimates that by the year 2000, approximately 50 percent of the 16 million fleet vehicles in the United States will be powered by alternative fuels such as CNG. Under the Energy Policy Act of 1992 and the Clean Air Act Amendment of 1990, the following are considered potential alternative fuels:

(a) Methanol;

(b) Hydrogen;

(c) Ethanol;

(d) Coal-derived liquids;

(e) Propane;

(f) Biological materials;

(g) Natural gas;

(h) Reformulated gasoline;

(i) Electricity;

(j) "Clean" diesel.

The alternative fuels considered most viable in the near future are compressed natural gas (CNG), liquefied petroleum gas (LPG), liquefied natural gas (LNG), and methanol.

F-2 Compressed Natural Gas. CNG has some excellent physical and chemical properties that make it clearly a safer automotive fuel than gasoline or LPG, provided well-designed carrier systems and operational procedures are followed. Although CNG has a relatively high flammability limit, its flammability range is relatively narrow compared to the ranges for other fuels.

In air at ambient conditions, a CNG volume of at least 5 percent is necessary to support continuous flame propagation, compared to about 2 percent for LPG and 1 percent for gasoline vapor. Thus, considerable fuel leakage is necessary in order to render the mixture combustible. Moreover, fires involving combustible mixtures of CNG are relatively easy to contain and extinguish.

Since natural gas is lighter than air, in the event of a leak, it normally dissipates harmlessly into the atmosphere instead of pooling. However, in a tunnel environment, this can lead to pockets of gas collecting in the overhead structure. Also, since natural gas can ignite only in a range of 5 percent to 15 percent volume of natural gas in air, leaks are not likely to ignite because of a lack of sufficient oxygen.

Additionally, the fueling system for CNG is one of the safest in existence. The vigorous storage requirements and greater strength of CNG cylinders compared to those of gasoline contribute to the superior safety record of CNG automobiles.

F-3 Liquefied Petroleum Gas. There is a growing awareness of the economic advantages of using LPG as a vehicular fuel. These advantages include longer engine life, increased travel time between oil and oil filter changes, longer and better performance from spark plugs, nonpolluting exhaust emissions, and, in most cases, mileage comparable to that of gasoline. LPG normally is delivered as a liquid and can be stored at 100.4°F (38°C) on vehicles under a design pressure of 250 psi to 312.5 psi (1624 kPa to 2154 kPa). It is a natural gas and petroleum derivative. On one hand, it is costly to store because a pressure vessel is required. On the other hand, if engulfed in a fire, its heating could result in a rapid increase in pressure, even if the outside temperature is not excessive relative to its vapor pressure characteristics. Rapid pressure increase can be mitigated by venting the excessive buildup of pressure through appropriate relief valves.

F-4 Methanol (Alcohol-Fueled Vehicles). Currently, methanol is used primarily as a chemical feed-stock for the production of chemical intermediates and solvents. Under the EPA's restrictions, it is being used as a substitute for lead-based octane enhancers in the form of methyl tertiary-butyl ether (MTBE) and as a viable method for vehicle emission control. MTBE is not consumed as a fuel substitute but is used as a gasoline additive.

The hazards of methanol production, distribution, and use are comparable to those of gasoline. Unlike gasoline, however, methanol vapors in a fuel tank are explosive at normal ambient temperature. Saturated vapors above nondiluted methanol in an enclosed tank are explosive at 50°F to 109.4°F (10°C to 43°C). A methanol flame is invisible, so a colorant or gasoline has to be added to enable detection.

Appendix G The Memorial Tunnel Fire Ventilation Test Program

This Appendix is not a part of the recommendations of this NFPA document but is included for informational purposes only.

G-1 General. The primary purpose for controlling smoke in a tunnel is to protect life (i.e., to allow safe evacuation of the tunnel). This involves creating a safe evacuation path for both motorists and any operating personnel located within the tunnel. The secondary purpose of smoke control ventilation is to assist fire-fighting personnel in accessing the fire site, by again providing a clear path to the site if possible.

The tunnel ventilation system is not designed to protect property, although the effect of ventilation in diluting smoke, thus recovering some of the heat, results in reduced damage to the facilities and vehicles. The continued reduction of vehicle emissions has shifted the focus of the ventilation engineer from a design based on dilution of emission contaminants to a design based on the control of smoke in a fire emergency.

Despite this increasing focus on life safety and fire control in modern highway tunnels, no uniform standards for fire emergency ventilation or other fire control means within highway tunnels have been established in the United States.

G-2 Ventilation Concepts. The ventilation concepts that have been applied to highway tunnels have been based on theoretical and empirical values, not on the results of full-scale tests. Accordingly, the design approach currently utilized to detect, control, and suppress fire and smoke within highway tunnels has become a controversial issue among tunnel design engineers, owners, operators, and fire fighters throughout the world.

While most highway tunnels have ventilation systems with smoke control operating modes, there is limited scientific data to support opinions or code requirements regarding the capabilities of various types of ventilation systems to control heat and smoke effectively.

G-3 Investigations. Engineering investigations of ventilation operating strategies and performance in full-scale fire situations were authorized by the Massachusetts Highway Department and the U.S. Federal Highway Administration to be performed in the Memorial Tunnel. The American Society of Heating, Refrigerating and Air-Conditioning Engineers Technical Committee 5.9 report, ASHRAE TC 5.9, "Enclosed Vehicular Facilities," had identified the need for a comprehensive full-scale test program in the early 1980s.

Technical Committee 5.9 was commissioned in 1989 to form a subcommittee, the Technical Evaluation Committee (TEC), to develop a "Phase 1 Concept Report" and work scope. This report outlined the objectives of the testing program, which included identification of appropriate means to account for the effects of fire size, tunnel grade and cross section, direction of traffic flow (unidirectional or bi-directional), altitude, type of ventilation system, and any other parameters that could have a significant influence on determining the ventilation capacity and operational procedures needed for safety in a fire situation.

Establishing specific approaches to permit effective reconfiguration for both new and existing tunnel facilities was deemed of equal importance. The goals and test matrices developed and documented in the "Phase 1 Concept Report" evolved into the described test plan.

The purpose of the Memorial Tunnel Fire Ventilation Test Program was to develop a database that provides tunnel design engineers and operators with an experimentally proven means to determine the ventilation rate and system configuration that provides effective smoke control during a tunnel fire.

It was even more important to establish specific operational strategies to permit effective reconfiguration of ventilation parameters for existing tunnel facilities. While the life safety issue is paramount, it should be recognized that significant cost differentials exist among the various types of ventilation systems. In the instance where more than one ventilation configuration offers an acceptable level of fire safety, the project's overall life-cycle cost needs to be addressed to identify the option with the optimum cost benefit.

In addition, the impact of ventilation systems that cause horizontal roadway-level airflow on the effectiveness of fire suppression systems (such as foam deluge sprinklers) can be better determined on the basis of full-scale test results.

G-4 The Test Facility. The Memorial Tunnel is a two-lane, 2800-ft (854-m) highway tunnel located near Charleston, WV, originally built in 1953 as part of the West Virginia Turnpike (I-77). The tunnel has a 3.2-percent uphill grade from the south to the north tunnel portal. The original ventilation system was a transverse type, consisting of a supply fan chamber at the south portal and an exhaust fan chamber at the north portal.

The tunnel has been out of service since it was bypassed by an open-cut section of a new six-lane interstate highway in 1987. The existing ventilation equipment was removed to allow installation of new variable speed, reversible, axial flow central ventilation fans. The equipment rooms were modified to accept the ventilation components needed to allow supply or exhaust operation from both ends of the tunnel.

There are six fans, three each in the modified north and south portal fan rooms. Each of the fans has a capacity to supply or exhaust 200,000 cfm (94.4 m^3/s), and they are fitted with vertical discharges to direct the smoke away from the test facility and the nearby interstate highway.

The existing overhead air duct, formed by a concrete ceiling above the roadway, is split into longitudinal sections that can serve as either supply or exhaust ducts, and a mid-tunnel duct bulkhead has been installed to allow a two-zone ventilation operation. Openings in the duct dividing wall and duct bulkhead have been designed to create airflow patterns similar to those that would be observed if the dividing wall was not present. The width of the ducts varies linearly along the length of the tunnel to provide maximum area at the point of connection to the fan rooms above the tunnel portals.

High temperature insulation was applied extensively to various structural elements, including the concrete ceiling and ceiling hangers, as well as all the utilities, instrumentation support systems, wiring, gas sampling lines, CCTV camera cabinets, and all other related items that are exposed to high tunnel fire temperatures.

G-5 Fire Size. Fires with heat release rates ranging from 20 MW — equivalent to a bus or truck fire — to 50 MW — equivalent to a flammable spill of approximately 100 gal (400 L) to 100 MW — equivalent to a hazardous material fire or flammable spill of approximately 200 gal (800 L) were produced. The fires were generated in four floor-level steel pans in which a metered flow of No. 2 fuel oil up to 2 in. (5 cm) deep was floated on top of a 6-in. (15-cm) layer of water.

Engineering estimates concluded that a fire heat release rate of approximately 10 MW would be produced when an exposed fire surface area of 16 ft^2 (1.5 m^2) is provided. The total surface area of the pans used for a 100-MW fire is 478 ft^2 (44.4 m^2).

The actual burning rate differed somewhat from that used for the engineering estimate, due to effects such as heat re-radiation from the tunnel walls and varying ventilation flow rates. Therefore, the measured tunnel conditions were interpreted to determine a measured heat release rate. The ventilation systems configured and tested under varying flow rates and varying heat release rates, with one or two zones of ventilation, included:

(a) Transverse ventilation;

(b) Partial transverse ventilation;

(c) Transverse ventilation with point extraction;

(d) Transverse ventilation with oversized exhaust ports;

(e) Natural ventilation;

(f) Longitudinal ventilation with jet fans.

When the first four series of tests in Section G-4(a) through (f) were completed, the tunnel ceiling was removed to conduct the natural ventilation tests, followed by the installation of jet fans at the crown of the tunnel for the longitudinal jet fan-based ventilation tests.

A fire suppression system that was available to suppress the fire in an emergency was installed; however, it was used during several tests to evaluate the impact of ventilation airflow on the operation of a foam suppression system.

G-6 Data Collection. All of the measured values were entered into a data acquisition system (DAS) that monitored and recorded data from all field instruments for on-line and historical use. Various trend graphs and reports were generated from the data acquisition system. The DAS consisted of five data acquisition units (DAUs), three located in the tunnel and two in the portal electrical equipment rooms. The DAS central processing units (CPUs), operator consoles, dataloggers, printer, and tape drives were located in the control trailer. The accuracy of the DAS input/output cards is ±0.05 percent.

The measurement of tunnel air temperature was accomplished through the use of thermocouples located at various cross sections throughout the length of the tunnel.

In total, there were approximately 1450 instrumentation sensing points. Each sensing point was monitored and recorded once every second during a test, which lasted from 20 minutes to 45 minutes.

Approximately 4 million data points were recorded during a single test. All test data was recorded on tapes in a control center trailer, where control operators monitored and controlled each test.

There were instrument trees located at ten tunnel cross sections, which were designed to measure airflow to a modified ASHRAE traverse method. At these locations, Type K thermocouples with an expected accuracy of ± 0.75 percent were located at each air velocity sensor and measured air temperature from 32°F to 2500°F (0°C to 1370°C).

Additional temperature measurements also were taken at five other tunnel cross sections and at two locations (15 m) outside of the tunnel portals. The measurement of air velocity in the tunnel under test conditions was accomplished through the use of differential pressure instrumentation designed to measure very low pressure ranges from 0 psi to $^{1}/_{4}$ psi (0 Pa to 61 Pa).
Temperatures in the vicinity of the bidirectional pilot tubes and the ambient pressure were combined with the measured pressure to calculate the air velocity.

A gas sampling system extracted sample gas from specific tunnel locations to analysis cabinets located in the electrical equipment rooms. Sample gases were analyzed within the analysis cabinets for two ranges of CO, CO_2, and total hydrocarbon context (THC). The analyzers were housed in climate-controlled cabinets.

To ensure personnel safety, methane gas could be detected at the test fire location through the use of individual in-situ electromechanical cell-type analyzers at the control trailer. In addition, portable detectors capable of detecting carbon monoxide, total hydrocarbon, oxygen, and methane were provided for personnel safety when entering the tunnel after fire tests.

Two meteorological towers located outside of the north and south tunnel portals include instrumentation that monitored and recorded ambient dry and wet bulb air temperatures, barometric pressure, wind speed, and wind direction.

These weather-related parameters were monitored for over $1^1/_2$ years to track weather conditions to assist in planning, scheduling, and conducting the tests.

G-7 Instrumentation. Specific instrumentation was provided to monitor and record the following variables during the fire tests:

(a) Air temperature;

(b) Air velocity;

(c) Gas concentrations.

G-8 Cameras. The closed-circuit television (CCTV) system originally included six cameras, two located within 203 ft to 217 ft (62 m to 66 m) of the fire area, two located outside of the tunnel (near the portals), and two located on the north and south meteorological towers. Another roadway-level camera was added during the tests that was located 1100 ft (335 m) north of the fire to secure added video footage of smoke movement.

Each of the four outdoor cameras had pan-tilt-zoom capabilities. They were used to monitor the fire area, visibility obscuration, and smoke stratification. Instrumentation to monitor and record important parameters of the fire suppression system, the chilled water system used for equipment cooling, and the compressed air and fuel oil systems also were included.

G-9 Conclusions. The Memorial Tunnel Fire Ventilation Test Program represents a unique opportunity to evaluate and develop design methods and operational strategies leading to safe underground transportation facilities. This comprehensive test program, which began with the initial fire tests in September 1993 and concluded with the final tests in March 1995, produced much-needed data that was acquired in a full-size facility, under controlled conditions and over a wide range of system parameters.

The results of the test program were processed and made available to the professional community for use in the development of emergency tunnel ventilation design and emergency operational procedures in late 1995, titled: "Memorial Tunnel Fire Ventilation Test Program Test Report," prepared for Massachusetts Highway Department, prepared by Bechtel/Parsons Brinckerhoff, November, 1995.

Appendix H Referenced Publications

H-1 The following documents or portions thereof are referenced within this recommended practice for informational purposes only and thus are not considered part of the recommendations of this document. The edition indicated for each reference is the current edition as of the date of the NFPA issuance of this document.

H-1.1 NFPA Publications. National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.

NFPA 30, *Flammable and Combustible Liquids Code*, 1996 edition.

NFPA 130, *Standard for Fixed Guideway Transit Systems*, 1995 edition.

NFPA 259, *Standard Test Method for Potential Heat of Building Materials*, 1993 edition.

H-1.2 Other Publications.

H-1.2.1 ANSI Publication. American National Standards Institute, 11 West 42nd Street, New York, NY 10036.

ANSI/IEE 268, *American National Standard for Metric Practice*, 1992.

H-1.2.2 ASHRAE Publication. American Society of Heating, Refrigerating and Air Conditioning Engineers, Inc., 1725 Tullie Circle, Atlanta, GA 30329.

ASHRAE TC 5.9, "Enclosed Vehicular Facilities."

H-1.2.3 ASTM Publications. American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103.

ASTM E 136, *Standard Test Method for Behavior of Materials in a Vertical Tube Furnace at 750 Degrees C*, A-1994.

ASTM E 380, *Standard Practice for Use of the International System of Units (SI) (the Modernized Metric System)*, 1993.

H-1.2.4 *Transportation Regulations at Tunnel and Bridge Facilities Hazardous Materials*, The Port Authority of New York and New Jersey, One World Trade Center, New York, New York 10048, November 23, 1987.

H-1.2.5 *Subway Environmental Design Handbook, Vol. I, Principles and Applications*, 2nd edition, 1976, Associated Engineers — A Joint Venture: Parsons Brinckerhoff Quade & Douglas, Inc., Delew Cather and Company; Kaiser Engineers, under the direction of Transit Develop Corporation, Inc.

NFPA 505

1996 Edition

Fire Safety Standard for Powered Industrial Trucks Including

1996 Edition

This edition of NFPA 505, *Fire Safety Standard for Powered Industrial Trucks Including Type Designations, Areas of Use, Conversions, Maintenance, and Operation,* was prepared by the Technical Committee on Industrial Trucks and acted on by the National Fire Protection Association, Inc., at its Annual Meeting held May 20-23, 1996, in Boston, MA. It was issued by the Standards Council on July 18, 1996, with an effective date of August 9, 1996, and supersedes all previous editions.

Changes other than editorial are indicated by a vertical rule in the margin of the pages on which they appear. These lines are included as an aid to the user in identifying changes from the previous edition.

This edition of NFPA 505 was approved as an American National Standard on July 26, 1996.

Origin and Development of NFPA 505

Chapter 1 (formerly Part A) of this standard was originally designated as NFPA 505A and was first adopted by the Association in 1951. Chapters 4 and 5 (formerly Parts A and B), "Maintenance of Industrial Trucks" and "Operation of Industrial Trucks," were originally adopted in 1952 and published by the NFPA under the designation NFPA No. 505B, C, *Standards for the Maintenance and Safe Operation of Industrial Trucks*. The combining of the three texts into one document, NFPA 505, was accomplished in 1955. Revisions were made in 1955, 1957, 1963, 1965, 1966, 1967, 1968, 1969, 1971, 1972, 1973, 1975, 1978, 1982, and 1987. The 1971 edition was the first edition to be approved by ANSI.

In the 1992 edition, Group F was added to the list of classified locations to correlate with the *National Electrical Code*®.

In the 1996 edition, changes were made to the types of trucks listed for operation in Class I, Division 2, locations, and a new DX type designation was added. Also, a new section on compressed natural gas (CNG) was added and related changes to the chapters on dual-fuel trucks and converted trucks were made.

Charles L. Crocker, Burlington Industries Inc., NC

Wayne Doversberger, Underwriters Laboratories Inc., IL

John A. Gutauskas, Factory Mutual Research Corp., MA

P. G. Tyrer, Pyroban Ltd, England

Kenneth R. VanHook, Mitsubishi Caterpillar Forklift America Inc., TX
Rep. Industrial Truck Assn.

Alternates

William H. Gray, Underwriters Laboratories Inc., IL
(Alt. to W. Doversberger)

Jerry L. Harpin, Factory Mutual Research Corp., MA
(Alt. to J. A. Gutauskas)

William J. Montwieler, Industrial Truck Assn., DC
(Alt. to K. R. VanHook)

Richard Ortisi-Best, NFPA Staff Liaison

This list represents the membership at the time the Committee was balloted on the text of this edition. Since that time, changes in the membership may have occurred.

NOTE: Membership on a Committee shall not in and of itself constitute an endorsement of the Association or any document developed by the Committee on which the member serves.

Committee Scope: This Committee shall have primary responsibility for documents on the safe use, maintenance, and operation of industrial trucks and other material-handling equipment to minimize fire hazards.

NFPA 505
Fire Safety Standard for
Powered Industrial Trucks Including Type Designations, Areas of Use, Conversions, Maintenance, and Operation

1996 Edition

NOTICE: An asterisk (*) following the number or letter designating a paragraph indicates explanatory material on that paragraph in Appendix A.
Information on referenced publications can be found in Chapter 6 and Appendix B.

Chapter 1 Type Designations and Areas of Use

1-1 Scope.

This standard shall apply to fork trucks, tractors, platform lift trucks, motorized hand trucks, and other specialized industrial trucks powered by electric motors or internal combustion engines. This standard shall not apply to compressed air-operated or nonflammable compressed gas-operated industrial trucks, farm vehicles, or automotive vehicles for highway use.

1-2 General.

1-2.1

The design and installation of the compressed natural gas (CNG) fuel systems on CNG- and dual-fuel- (gasoline and CNG) powered industrial trucks shall be in accordance with the applicable provisions of NFPA 52, *Standard for Compressed Natural Gas (CNG) Vehicular Fuel Systems*.

1-2.2

The design and installation of the LP-Gas fuel systems on LP-Gas- and dual-fuel- (gasoline and LP-Gas) powered industrial trucks shall be in accordance with the applicable provisions of NFPA 58, *Standard for the Storage and Handling of Liquefied Petroleum Gases*.

1-2.3

Approved powered industrial trucks, as referred to in this standard, are those trucks listed by a testing laboratory for the use intended. Trucks shall be tested and labeled in accordance with UL 558, *Standard for Safety Industrial Trucks, Internal Combustion Engine-Powered*, or UL 583, *Standard for Safety Electric-Battery-Powered Industrial Trucks.*

1-3 Equivalency.

Nothing in this standard is intended to prevent the use of new methods or devices, provided that sufficient technical data is submitted to the authority having jurisdiction to demonstrate that the proposed method or device is equivalent in quality, strength, fire endurance, effectiveness, durability, and safety to those prescribed by this standard.

1-4* Definitions.

Approved.* Acceptable to the authority having jurisdiction.

Authority Having Jurisdiction.* The organization, office, or individual responsible for approving equipment, an installation, or a procedure.

Labeled. Equipment or materials to which has been attached a label, symbol, or other identifying mark of an organization that is acceptable to the authority having jurisdiction and concerned with product evaluation that maintains periodic inspection of production of labeled equipment or materials and by whose labeling the manufacturer indicates compliance with appropriate standards or performance in a specified manner.

Listed.* Equipment, materials, or services included in a list published by an organization acceptable to the authority having jurisdiction and concerned with evaluation of products or services that maintains periodic inspection of production of listed equipment or materials or periodic evaluation of services and whose listing states either that the equipment, material, or service meets identified standards or has been tested and found suitable for a specified purpose.

Shall. Indicates a mandatory requirement.

Should. Indicates a recommendation or that which is advised but not required.

Type Designation.* A system for identifying types of powered industrial trucks for operation in nonclassified and classified areas. [*See (a) through (r), which follow*.]

(a) *Type CN* units are compressed natural gas-powered units having minimum acceptable safeguards against inherent fire hazards.

(b) *Type CNS* units are compressed natural gas-powered units that, in addition to meeting the requirements for Type CN units, are provided with additional safeguards to the exhaust, fuel, and electrical systems.

(c) *Type D* units are diesel-powered units having minimum acceptable safeguards against inherent fire hazards.

(d) *Type DS* units are diesel-powered units that, in addition to meeting all the requirements for Type D units, are provided with additional safeguards to the exhaust, fuel, and electrical systems.

(e) *Type DY* units are diesel-powered units having all the safeguards of Type DS units and, in addition, any electrical equipment is completely enclosed. They are equipped with temperature limitation features.

(f) *Type DX* units are diesel-powered units that differ from Type DS and DY units in that the diesel engine and the electrical fittings and equipment are so designed, constructed, and assembled that the units can be used in atmospheres containing specifically named flammable vapors, dusts, and, under certain conditions, fibers. Type DX units are specifically tested and classified for use in Class I, Group D locations or for Class II, Group F or G locations as defined in NFPA 70, *National Electrical Code*®□.

(g) *Type E* units are electrically powered units having minimum acceptable safeguards against inherent fire and electrical shock hazards.

(h) *Type ES* units are electrically powered units that, in addition to meeting all the requirements for Type E units, are provided with additional safeguards to the electrical system to prevent the emission of hazardous sparks and to limit surface temperatures.

(i) *Type EE* units are electrically powered units that, in addition to meeting all the requirements for Types E and ES units, have their electric motors and all other electrical equipment completely enclosed.

(j) *Type EX* units are electrically powered units that differ from a Type E, ES, or EE unit in that the electrical fittings and equipment are so designed, constructed, and assembled that the units can be used in atmospheres containing specifically named flammable vapors, dusts, and, under certain conditions, fibers. Type EX units are specifically tested and classified for use in Class I, Group D locations or for Class II, Group F or G locations as defined in NFPA 70, *National Electrical Code*.

(k) *Type G* units are gasoline-powered units having minimum acceptable safeguards against inherent fire hazards.

(l) *Type GS* units are gasoline-powered units that, in addition to meeting all the requirements for Type G units, are provided with additional safeguards to the exhaust, fuel, and electrical systems.

(m) *Type LP* units are liquefied petroleum gas-powered units having minimum acceptable safeguards against inherent fire hazards.

(n) *Type LPS* units are liquefied petroleum gas-powered units that, in addition to meeting the requirements for Type LP units, are provided with additional safeguards to the exhaust, fuel, and electrical systems.

(o) *Type G/CN* units operate on either gasoline or compressed natural gas having minimum acceptable safeguards against inherent fire hazards.

(p) *Type GS/CNS* units operate on either gasoline or compressed natural gas and, in addition to meeting all the requirements for Type G/CN units, are provided with additional safeguards to the exhaust, fuel, and electrical systems.

(q) *Type G/LP* units operate on either gasoline or liquefied petroleum gas having minimum acceptable safeguards against inherent fire hazards.

(r) *Type GS/LPS* units operate on either gasoline or liquefied petroleum gas and, in addition to meeting all the requirements for the Type G/LP units, are provided with additional safeguards to the exhaust, fuel, and electrical systems.

1-5 Hazard Classification.

1-5.1

The authority having jurisdiction shall determine the hazard classification of any specific location. The location shall have been classified prior to the consideration of the use of industrial trucks therein, and the type of industrial truck required shall be as provided in Section 1-6 for that location.

1-5.2

Several areas of any single plant or building could have different hazard classifications. The authority having jurisdiction shall limit the use of industrial trucks in classified areas in a plant or building in accordance with the hazard classification of such areas. The responsibility for the enforcement of restricted use in such areas shall be that of the management.

1-5.3

The industrial trucks specified in Section 1-6 are the minimum types required. Industrial trucks having greater safeguards shall be permitted to be used.

1-6 Specific Areas of Use.

Table 1-6 provides a summary of industrial truck types for specific areas of use and was developed from information contained in this section.

The references to class/group/division contained in parentheses in the subsection headings of this section correspond to classifications in accordance with NFPA 70, *National Electrical Code*, and are provided for the convenience of the user.

Table 1-6 Summary Table on Use of Powered Industrial Trucks as Described in Chapter 1

Table 1-6 Summary Table on Use of Powered Industrial Trucks as Described in Chapter 1

Locations	CNG-Powered		Diesel-Powered				Electrically Powered				Gasoline-Powered		LP-Gas-Powered		Dual-Fuel-Powered			
	CN	CNS	D	DS	DY	DX	E	ES	EE	EX	G	GS	LP	LPS	G/CN	GS/CNS	G/LP	G…
Class I Division 1																		
Group A																		
Group B																		
Group C																		
Group D						A				A								
Class I Division 2																		
Group A					K	K			K	K								
Group B		K			K	K			K	K		K		K		K		
Group C		K			K	K			K	K		K		K		K		
Group D		J			A	A			A	A		J		J		J		
Class II Division 1																		
Group E						J				J								
Group F						A†				A†								
Group G						A				A								
Class II Division 2																		
Group F[1]		J		J	A	A		J	A	A		J		J		J		
Group G		J		J	A	A		J	A	A		J		J		J		
Class III Division 1		J		J	A	A		J	A	A		J		J		J		
Class III Division 2		A		A	A	A	J	A	A	A		A		A		A		

Key to Table Symbols

A = Type truck authorized for location described.

J = Type truck authorized for location described with approval of the authority having jurisdiction.

† = Where dust has resistivity of 10^5 ohm-cm, use J.

¹ = Where dust has resistivity of 10^5 ohm-cm or greater.

K = Type truck authorized to be determined by the authority having jurisdiction.

Type truck not authorized in location described.

1-6.1* Areas Containing Certain Flammable Gases or Vapors Where Power-Operated Industrial Trucks Shall Not Be Used (Class I, Groups A, B, and C, Division 1).

Power-operated industrial trucks shall not be used in these locations.

For examples of those chemicals for which mixtures of their vapors in air are classified as Class I, Group A, B, or C, see Section 500-3 of NFPA 70, *National Electrical Code*, and A-1-6.1 of this standard.

1-6.2 Areas Where Vapors of Flammable Liquids and Some Gases Exist under Normal Operating Conditions (Class I, Group D, Division 1).

1-6.2.1* Approved power-operated industrial trucks designated as Type DX or EX and classified for Class I, Group D chemicals shall be used in such locations containing gases or vapors.

1-6.2.2 Class I, Group D, Division 1 areas include locations where volatile flammable liquids or liquefied flammable gases are transferred from one container to another; interiors of spray booths and areas in the vicinity of spraying and painting operations where volatile flammable solvents are used; locations containing open tanks or vats of volatile flammable liquids; drying rooms or compartments for the evaporation of flammable solvents; locations containing fat and oil extraction apparatus using volatile flammable solvents; portions of cleaning and dyeing plants where hazardous liquids are used; gas generator rooms and other portions of gas manufacturing plants where flammable gas could escape; inadequately ventilated pump rooms for flammable gas or for volatile flammable liquids; the interiors of refrigerators and freezers in which volatile flammable materials are stored in open, lightly stoppered, or easily ruptured containers; and all other locations where hazardous concentrations of flammable vapors or gases are likely to occur in the course of normal operations.

1-6.3 Areas Where Volatile Flammable Liquids and Their Vapors or Flammable Gases Are Normally Confined (Class I, Group D, Division 2).

1-6.3.1 Approved power-operated industrial trucks designated as Type DX, DY, EE, or EX (classified for Class I, Group D locations) shall be used in locations where volatile flammable liquids or flammable gases are handled, processed, or used, but in which these liquids, vapors, or gases normally are confined within closed containers or closed systems from which they can escape only in the event of accidental rupture or breakdown of such containers or systems, or in the event of abnormal operation of equipment; in locations in which ignitible concentrations of gases or vapors are normally prevented by positive mechanical ventilation but that might become hazardous through failure or abnormal operation of the ventilating equipment; or in locations adjacent to Class I, Division 1 locations and to which ignitible concentrations of gases or vapors might occasionally be communicated, unless such communication is prevented by adequate positive-pressure ventilation from a source of clean air and effective safeguards against ventilation failure are provided.

1-6.3.2 Class I, Group D, Division 2 areas include locations where volatile flammable liquids or flammable gases or vapors are used, but that, in the judgment of the authority having jurisdiction, would become hazardous only in the event of an accident or some unusual operating condition. The quantity of flammable material that might escape during an accident, the adequacy of ventilating equipment, the total area involved, and the record of the industry or business with respect to explosions or fires are all factors that should receive consideration in determining whether or not a particular type of truck possesses sufficient safeguards for the location.

1-6.4 Areas Containing Combustible Metal Dusts and Other Combustible Dusts Having Resistivity of Less than 10^2 ohm-cm (Class II, Groups E and F, Division 1).

1-6.4.1 Power-operated industrial trucks shall not be used in locations containing hazardous concentrations of metal dust, including aluminum and magnesium and their commercial alloys or other dusts of similarly hazardous characteristics having resistivity of less than 10^2 ohm-cm.

Exception: Approved power-operated industrial trucks designated as Type DX or EX shall be permitted to be used in such locations, subject to special investigation of both the truck and the *specific area of use by the authority having jurisdiction.*

1-6.4.2 In atmospheres where the dust of magnesium, aluminum, or aluminum bronze might be present, truck fuses, switches, motor controllers, and circuit breakers shall have enclosures specifically approved for such locations.

1-6.5 Areas Containing Combustible Dusts in Suspension Having Resistivity of 10^2 ohm-cm or Greater and Less than 10^8 ohm-cm (Class II, Group F, Division 1).

1-6.5.1 Power-operated industrial trucks shall not be used in locations containing hazardous concentrations of electrically conductive Group F dusts having a resistivity less than 10^5 ohm-cm.

Exception: Approved power-operated industrial trucks designated as Type DX or EX shall be permitted to be used in such locations, subject to special investigation of both the truck and the specific area of use by the authority having jurisdiction.

1-6.5.2 Approved power-operated industrial trucks designated as Type DX or EX (classified for Class II, Group F locations) shall be used in locations in which electrically nonconductive Group F dust having a resistivity of 10^5 ohm-cm or greater but less than 10^8 ohm-cm is or could be in suspension under normal operating conditions in quantities sufficient to produce explosive or ignitible mixtures or where mechanical failure or abnormal operation of machinery or equipment might cause such mixtures to be produced.

1-6.5.3* Class II, Group F, Division 1 areas include locations containing carbon black, charcoal, coal, and coke dusts that have more than 8 percent total volatile material (coal and coke dust in accordance with ASTM D 3175, *Standard Test Method for Volatile Matter in the Analysis Sample of Coal and Coke*) or atmospheres containing those dusts sensitized by other materials so that they present an explosion hazard.

1-6.6 Areas Containing Combustible Dusts in Suspension Having Resistivity of 10^8 ohm-cm or Greater (Class II, Group G, Division 1).

1-6.6.1 Approved power-operated industrial trucks designated as Type DX or EX (classified for Class II, Group G locations) shall be used in locations in which combustible dust having resistivity of 10^8 ohm-cm or greater is or could be in suspension under normal operating conditions in quantities sufficient to produce explosive or ignitible mixtures, or where mechanical failure or abnormal operation of machinery or equipment might cause such mixtures to be produced.

1-6.6.2 Class II, Group G, Division 1 areas include locations such as the working areas of grain-handling and storage plants; rooms containing grinders or pulverizers, cleaners, graders, scalpers, open conveyors or spouts, open bins or hoppers, mixers or blenders, automatic or hopper scales, packing machinery, elevator heads and boots, stock distributors, and dust and stock collectors (except all-metal collectors vented to the outside); and all similar dust-producing machinery and equipment in grain-processing plants, starch plants, sugar-pulverizing plants, malting plants, wood flour plants, hay-grinding plants, and other occupancies of similar nature where combustible dust having resistivity of 10^8 ohm-cm or greater might, under normal operating conditions, be present in the air in quantities sufficient to produce explosive or ignitible mixtures.

1-6.7 Areas Where Combustible Dusts Having Resistivity of 10^5 ohm-cm or Greater are Present but Not Normally in Suspension in the Atmosphere (Class II, Groups F and G, Division 2).

1-6.7.1 Approved power-operated industrial trucks designated as Type DX, DY, EE, or EX (classified for Class II, Group F or G locations, as appropriate) shall be used in locations in which combustible dust having resistivity of 10^5 ohm-cm or greater is not normally in suspension in the air or is not likely to be thrown into suspension by the normal operation of equipment or apparatus in quantities sufficient to produce explosive or ignitible mixtures but where deposits or accumulations of such dust might be ignited by arcs or sparks originating in the truck.

1-6.7.2 In locations where dangerous concentrations of suspended dust having resistivity of 10^5 ohm-cm or greater would not be likely, approved power-operated industrial trucks designated as Type CNS, DS, ES, GS, LPS, GS/CNS, or GS/LPS shall be permitted to be used if approved for such location by the authority having jurisdiction. These locations include rooms and areas containing only closed spouting and conveyors, closed bins or hoppers, or machines and equipment from which appreciable quantities of dust could escape only under abnormal operating conditions; rooms or areas into which explosive or ignitible concentrations of suspended dust might be communicated only under abnormal operating conditions; rooms or areas where the formation of explosive or ignitible concentrations of suspended dust is prevented by the operation of effective dust control equipment; warehouses and shipping rooms where dust-producing materials are stored or handled only in bags or containers; and other similar locations.

1-6.8 Areas Where Easily Ignitible Fibers or Materials Producing Combustible Flyings Are Handled, Manufactured, or Used (Class III, Division 1).

1-6.8.1* Approved power-operated industrial trucks designated as Type DX, DY, EE, or EX shall be used in locations that are classified because of the presence of easily ignitible fibers or materials producing combustible flyings but in which such fibers or flyings are not likely to be in suspension in the air in quantities sufficient to produce ignitible mixtures.

1-6.8.2 Locations where easily ignitible fibers or flyings are found usually include some portions of rayon, cotton, and other textile mills; combustible fiber manufacturing and processing plants; cotton gins and cottonseed mills; flax-processing plants; clothing-manufacturing plants; woodworking plants (except wood flour plants); and establishments and industries involving similar processes or conditions.

A wood flour plant shall be considered to be a Class II, Group G, Division 1 location as defined in 1-6.6.2.

Easily ignitible fibers and flyings include rayon, cotton (including cotton linters and cotton waste), sisal or henequen, istle, jute, hemp, tow, cocoa fiber, oakum, baled waste kapok, Spanish moss, excelsior, sawdust, wood chips, and other materials of similar nature.

1-6.9 Areas Where Easily Ignitible Fibers Are Stored or Handled (Class III, Division 2).

Exception: In process of manufacture.

1-6.9.1 Approved power-operated industrial trucks designated as Type CNS, DS, DX, DY, ES, EE, EX, GS, LPS, GS/CNS, or GS/LPS shall be used in locations where easily ignitible fibers are stored or handled, including outside storage, but are not being processed or manufactured. Industrial trucks designated as Type E that have been used previously in these locations shall be permitted to be continued in use with the approval of the authority having jurisdiction.

1-6.10 Hazardous Areas Not Otherwise Classified.

The authority having jurisdiction shall determine which types of approved power-operated industrial trucks, if any, shall be used following an engineering survey of the property and an evaluation of the fire and explosion hazards.

1-6.11 Piers and Wharves.

1-6.11.1 Where it is determined that the location on piers and wharves for handling general cargo is not hazardous, any approved power-operated industrial truck designated as Type CN, D, E, G, LP, G/CN, or G/LP shall be permitted to be used, or trucks that conform to the requirements for these types shall be permitted to be used.

1-6.11.2 Where an area of a pier or wharf is determined to be hazardous, only approved power-operated industrial trucks specified for such locations in the preceding subsections shall be permitted to be used.

1-6.12 General Inside and Outside Storage.

1-6.12.1 Where it is determined that the location for general storage in warehouses or general outside storage is not hazardous, any approved power-operated industrial truck designated as Type CN, D, E, G, LP, G/CN, or G/LP shall be permitted to be used, or trucks that conform to the requirements for these types shall be permitted to be used.

1-6.12.2 Where the location for general storage in warehouses or general outside storage is determined to be hazardous, only approved power-operated industrial trucks specified for such a location in the preceding subsections shall be permitted to be used.

1-6.13 General Industrial or Commercial Properties.

1-6.13.1 Where it is determined that the location on a general industrial or commercial property for handling or processing materials (with storage being incidental to handling and processing), or both, is not hazardous, any approved power-operated industrial truck designated as Type CN, D, E, G, LP, G/CN, or G/LP shall be permitted to be used, or trucks that conform to the requirements for these types shall be permitted to be used.

1-6.13.2 Where the location on a general industrial or commercial property for handling or processing materials, or both, is determined to be hazardous, only approved power-operated industrial trucks specified for such a location in the preceding subsections shall be permitted to be used.

1-6.14 Converted Industrial Trucks.

1-6.14.1 Power-operated industrial trucks that previously have been approved for or that conform to the requirements for Type G for the use of gasoline for fuel, where converted to the use of liquefied petroleum gas fuel in accordance with Chapter 3, shall be permitted to be used in those locations where a Type G or LP truck has been specified in the preceding subsections.

1-6.14.2 Power-operated industrial trucks that previously have been approved for or that conform to the requirements for Type G for the use of gasoline for fuel, where converted to the use of dual fuels (gasoline and LPG) in accordance with Chapter 3, shall be permitted to be used in those locations where a Type G or LP truck has been specified in the preceding subsections.

1-6.14.3 Power-operated industrial trucks that previously have been approved for or that conform to the requirements for Type LP for the use of liquefied petroleum gas for fuel, where converted to the use of dual fuels (gasoline and LPG) in accordance with Chapter 3, shall be permitted to be used in those locations where a Type G or LP truck has been specified in the preceding subsections.

1-6.14.4 Power-operated industrial trucks that previously have been approved for or that conform to the requirements for Type LP for the use of liquefied petroleum gas for fuel, where converted to the use of gasoline for fuel in accordance with Chapter 3, shall be permitted to be used in those locations where Type G trucks have been specified in the preceding subsections.

1-6.14.5 Power-operated industrial trucks that previously have been approved for or that conform to the requirements for Type G/LP for the use of dual fuels, where converted to the sole use of gasoline for fuel in accordance with Chapter 3, shall be permitted to be used in those locations where Type G trucks have been specified in the preceding subsections.

1-6.14.6 Power-operated industrial trucks that previously have been approved for or that conform to the requirements for Type G/LP for the use of dual fuels, where converted to the sole use of liquefied petroleum gas for fuel in accordance with Chapter 3, shall be permitted to be used in those locations where Type LP trucks have been specified in the preceding subsections.

1-6.14.7 Power-operated industrial trucks that previously have been approved for or that conform to the requirements for Type G for the use of gasoline for fuel, where converted to the use of compressed natural gas fuel in accordance with Chapter 3, shall be permitted to be used in those locations where a Type G or CN truck has been specified in the preceding subsections.

1-6.14.8 Power-operated industrial trucks that previously have been approved for or that conform to the requirements for Type G for the use of gasoline for fuel, where converted to the use of dual fuels (gasoline and CNG) in accordance with Chapter 3, shall be permitted to be used in those locations where a Type G or CN truck has been specified in the preceding subsections.

1-6.14.9 Power-operated industrial trucks that previously have been approved for or that conform to the requirements for Type CN for the use of compressed natural gas for fuel, where converted to the use of gasoline for fuel in accordance with Chapter 3, shall be permitted to be used in those locations where a Type G or CN truck has been specified in the preceding subsections.

1-6.14.10 Power-operated industrial trucks that previously have been approved for or that conform to the requirements for Type CN for the use of compressed natural gas for fuel, where converted to the use of gasoline for fuel in accordance with Chapter 3, shall be permitted to be used in those locations where Type G trucks have been specified in the preceding subsections.

1-6.14.11 Power-operated industrial trucks that previously have been approved for or that conform to the requirements for Type G/CN for the use of dual fuels, where converted to the sole use of gasoline for fuel in accordance with Chapter 3, shall be permitted to be used in those locations where Type G trucks have been specified in the preceding subsections.

1-6.14.12 Power-operated industrial trucks that previously have been approved for or that conform to the requirements for Type G/CN for the use of dual fuels, where converted to the sole use of compressed natural gas for fuel in accordance with Chapter 3, shall be permitted to be used in those locations where Type CN trucks have been specified in the preceding subsections.

1-6.14.13 Power-operated industrial trucks previously designated Type CNS, GS, LPS, GS/CNS, or GS/LPS shall not be converted to the use of other fuels.

1-6.14.14 Power-operated industrial trucks previously approved for or that conform to the requirements for Type CN, G, LP, G/CN, or G/LP shall not be converted to Type CNS, GS, LPS, GS/CNS, or GS/LPS.

Chapter 2 Dual-Fuel Trucks

2-1 General.

A dual-fuel truck shall be defined as a truck equipped to be operated on either gasoline or LPG or to be operated on either gasoline or CNG without further modification.

2-2 Requirements.

2-2.1

Those parts of the fuel system that come into contact with gasoline shall meet the requirements for liquid fuel in accordance with UL 558, *Standard for Safety Industrial Trucks, Internal Combustion Engine-Powered*.

2-2.2

Those parts of the fuel system that come into contact with CNG fuel shall meet the requirements for CNG fuel in accordance with NFPA 52, *Standard for Compressed Natural Gas (CNG) Vehicular Fuel Systems*.

2-2.3

Those parts of the fuel system that come into contact with LPG fuel shall meet the requirements for LPG fuel in accordance with UL 558, *Standard for Safety Industrial Trucks, Internal Combustion Engine-Powered*.

2-2.4

Those parts of the fuel system that come into contact with both gasoline and LPG fuel or with both gasoline and CNG fuel shall be compatible with both fuels.

2-2.5* Fuel Changeover.

Where switching from CNG or LPG to liquid fuel, care shall be taken to ensure that there is no spillage of liquid fuel.

2-3 Nameplate Visibility.

The truck type designation (*see definitions in Section 1-4*) as shown on the nameplate and the type marker (*see 5-4.2*) shall not be covered over with paint so that their information is obscured.

Chapter 3 Converted Trucks

3-1* Conversion of Trucks.

Industrial trucks previously approved and classified by type designation (*see 1-6.14*) shall be permitted to be converted to another type, provided that the conversion results in a truck that embodies the features specified for the particular fuel to be used in accordance with Table 3-1.

Table 3-1 Permissible Truck Fuel Conversions

Original Approval and Classification	New Approval and Classification
Gasoline	LP-Gas
Gasoline or LP-Gas	Dual fuels
LP-Gas or Dual fuels	Gasoline
Dual fuels	LP-Gas
Gasoline	CNG
G/CNG	Dual fuels
CNG or Dual fuels	Gasoline
Dual fuels	CNG
LP-Gas	CNG
CNG	LP-Gas

3-2 Conversion Requirements.

3-2.1

A truck designated as Type G, LP, or G/LP that is converted to another of these designations shall conform to the requirements for the new designation selected in accordance with UL 558, *Standard for Safety Industrial Trucks, Internal Combustion Engine-Powered.*

3-2.2

Conversion kits for use on trucks designated as Type G, LP, or G/LP shall conform to the requirements for the type designation selected in accordance with UL 558, *Standard for Safety Industrial Trucks, Internal Combustion Engine-Powered*, and can be approved by a testing laboratory.

3-2.3

Conversion kits for use on trucks designated as Type CN, G, LP, G/CN, or G/LP shall include the items specified in 3-2.4. The installation of the kit shall be in accordance with 3-2.4. Where a listed conversion kit is used, a copy of the report shall be supplied to the authority having jurisdiction upon request.

3-2.4

Kits for conversion of CN, G, LP, G/CN, and G/LP trucks shall include:

(a) Step-by-step installation instructions with pictorial illustration (if necessary) for clarity.

(b) All parts required to complete the installation, including:

1. Functional components;
2. Mounting brackets and hardware;
3. Connecting wires, hoses, and fittings; and
4. Sealants, if required.

(c) A durable, corrosion-resistant plate, indicating the converted type designation of the truck, for permanent mounting adjacent to the manufacturer's name plate on the truck.

(d) A metal nameplate attached to the LPG-tank mounting identifying the fuel container assembly to be used where the conversion is to LPG and a removable fuel tank is to be used.

(e) A gasoline fuel tank, along with necessary mounting and connection hardware and installation instructions, where the conversion is from CNG or LPG to gasoline or dual fuels.

(f) Instructions for removal or deactivation of the present components, including the gasoline tank(s), where the conversion is from gasoline or dual fuels to CNG or LPG.

(g) A tank or tanks, as appropriate, along with the necessary mounting and connection hardware and installation instructions where the conversion is from LPG to CNG or dual fuels, or where from gasoline to CNG or dual fuels and the truck is not equipped with a CNG or gasoline fuel tank, or both.

(h) Instructions covering checks and tests to be performed after the conversion and prior to putting the truck into service.

3-2.5

When a conversion kit is installed, all original identification of approval or listing and type designation shall be removed, and the plate specified in 3-2.4(c) shall be installed in lieu thereof.

Chapter 4 Maintenance of Industrial Trucks

4-1 General.

The fire safety built into power-operated industrial trucks shall be maintained in accordance with the instructional and training material provided by the manufacturer. Any power-operated industrial truck not in safe operating condition shall be removed from service.

4-2 Precautions.

4-2.1

Repairs shall not be made in Class I, Class II, and Class III locations.

4-2.2

Repairs to the fuel and ignition systems of industrial trucks that involve fire hazards shall be conducted only in locations designated for such repairs.

4-2.3

Repairs to the electrical system of battery-powered industrial trucks shall be performed only after the battery has been disconnected.

4-3 Replacement Parts.

All parts of any industrial truck, particularly trucks approved for use in classified hazardous locations, needing replacement shall be replaced only with parts providing the same degree of fire safety as those used in the original design.

4-4 Mufflers.

Water mufflers shall be filled daily or as frequently as is necessary to prevent depletion of the supply of water below 75 percent of the filled capacity. Vehicles with mufflers having screens or other parts that might become clogged shall not be operated while such screens or parts are clogged. Any vehicle that emits hazardous sparks or flames from the exhaust system shall be removed from service immediately and shall not be returned to service until the cause for the emission of such sparks and flames has been eliminated.

4-5 Operating Temperature.

Where the temperature of any part of any truck is found to be in excess of its normal operating temperature and creates a hazardous condition, the vehicle shall be removed from service and shall not be returned to service until the cause for such overheating has been eliminated.

4-6 Fire Prevention.

Industrial trucks shall be kept in a clean condition and reasonably free of lint, excess oil, and grease. Noncombustible agents are preferred for cleaning trucks. Flammable liquids [those having flash points below 100°F (37.8°C)] shall not be used. Combustible liquids [those having flash points at or above 100°F (37.8°C)] shall be permitted to be used. Precautions regarding toxicity, ventilation, and fire hazard shall be appropriate for the agent or solvent used.

4-7 Antifreeze.

Where antifreeze is used in the engine cooling system, only glycol-based material shall be used.

4-8 Nameplate Visibility.

The truck type designations (*see definitions in Section 1-4*) as shown on the nameplate and the type markers (*see 5-4.2*) shall not be covered over with paint so that their identification information is obscured.

Chapter 5 Fuel Recharging, Marking, and Operation of Industrial Trucks

5-1 Fuel Handling and Storage.

5-1.1 Liquid Fuels (e.g., Gasoline and Diesel Fuel).

5-1.1.1 The storage and handling of liquid fuels shall be in accordance with NFPA 30, *Flammable and Combustible Liquids Code*, or NFPA 30A, *Automotive and Marine Service Station Code*, as applicable.

5-1.1.2* Trucks using liquid fuels shall be refueled only at locations designated for that purpose and from approved dispensing pumps.

5-1.1.3 Engines shall be stopped and the operator shall not be on or inside the truck during refueling.

5-1.1.4 Emergency refueling shall be from approved safety cans. Safety cans shall be inspected regularly for leaks and for damage to closures; faulty cans shall be replaced.

5-1.1.5 Spillage of fuel or overfilling of the vehicle fuel tank shall be avoided.

5-1.1.6 Smoking or open flames shall be prohibited in the refueling area.

5-1.2 Liquefied Petroleum Gas Fuel.

5-1.2.1 The storage and handling of liquefied petroleum gas (LP-Gas) shall be in accordance with NFPA 58, *Standard for the Storage and Handling of Liquefied Petroleum Gases*.

5-1.2.2 Filling of fuel containers that are permanently mounted on trucks and filling of removable DOT-type LP-Gas containers shall be done at locations designated for that purpose and in accordance with NFPA 58, *Standard for the Storage and Handling of Liquefied Petroleum Gases*.

5-1.2.3 LP-Gas containers shall not be dropped, thrown, rolled, or dragged.

5-1.2.4 LP-Gas containers shall not be overfilled.

5-1.2.5 The engine shall be stopped and the operator shall not be on or inside the truck during refueling.

5-1.2.6 Trained and designated personnel shall refill or exchange LP-Gas containers.

5-1.2.7 A soap solution shall be used to check for leaks. A match or open flame shall not be used.

5-1.2.8 Removable LP-Gas containers shall not be exchanged near, and LP-Gas-powered vehicles shall not be parked near, sources of heat, open flames, or similar sources of ignition or near open pits, underground entrances, elevator shafts, or other similar areas.

Exception: Open pits, underground entrances, elevator shafts, or similar areas that are adequately ventilated to prevent accumulations of LP-Gas.

5-1.2.9 Trucks equipped with permanently mounted LP-Gas containers shall be refueled outdoors.

5-1.2.10* Means shall be provided in the fuel system to minimize the escape of fuel when the containers are exchanged. This shall be accomplished by:

(a) Closing the valve on the LP-Gas container; and

(b) Using an approved automatic quick-closing coupling (a type that closes in both directions when uncoupled) in the fuel line. Where such an automatic quick-closing coupling is not used, the fuel line shall be emptied by allowing the engine to run until the fuel in the line is consumed.

5-1.2.11 Removable LP-Gas containers shall be mounted securely to prevent them from jarring loose, slipping, or rotating and shall be positioned so that the safety pressure relief valve opening is always in contact with the vapor space (top) of the container. This shall be accomplished by means of a substantial positioning pin engaging the cylinder, or an equivalent means, and a container clamp(s) that, where the container is properly installed, positions the container. A container and its fittings shall not extend beyond the platform of the industrial truck.

5-1.2.12 All reserve LP-Gas containers shall be stored and transported with the service valve closed. Safety relief valves shall have direct communication with the vapor space of the container at all times.

5-1.2.13 All LP-Gas containers shall be examined before refilling for the following defects or damage:

(a) Dents, scrapes, and gouges of the pressure vessel;

(b) Damage to the various valves and liquid level gauge;

(c) Debris in the relief valve;

(d) Damage to or loss of the relief valve cap;

(e) Indications of leakage at the valves or threaded connections; and

(f) Deterioration, damage, or loss of flexible seals in the filling or servicing connections.

Where examination reveals physical damage such as dents, scrapes, or gouges [*see 5-1.2.13(a)*] that materially weaken the structure of the LP-Gas container and render it unsafe for use, it shall be removed from service.

Where examination reveals damages specified above other than physical damage [*see 5-1.2.13(b) through (f)*] to the container, appropriate repairs shall be made before the container is refilled.

5-1.2.14 Smoking shall be prohibited in the container refilling area for either portable or permanently mounted containers and in the exchange area during the exchange of LP-Gas containers.

5-1.2.15 The service valve of the fuel container shall be closed whenever vehicles are parked overnight or stored indoors for a protracted time.

5-1.3 Compressed Natural Gas Fuel.

5-1.3.1 The compression, storage, handling and dispensing of CNG shall be located and conducted in accordance with NFPA 52, *Standard for Compressed Natural Gas (CNG) Vehicular Fuel Systems*.

5-1.3.2 The engine shall be stopped and the operator shall not be on or inside the truck during refueling.

5-1.3.3 Smoking and open flames shall be prohibited in the refueling area.

5-1.3.4 Each fuel supply container shall be mounted in a location to minimize damage from collision. A container and its fittings shall not extend beyond the platform of the industrial truck. Containers, valves, and hoses and fittings shall be protected from physical damage using the vehicle structure, valve protectors, or suitable guards in accordance with NFPA 52, *Standard for Compressed Natural Gas (CNG) Vehicular Fuel Systems*.

5-1.3.5 The refueling receptacle on a truck shall be supported firmly and shall incorporate a means to prevent the entry of dust, water, and other foreign material. Where the means used is capable of sealing the system pressure, it shall be capable of being depressurized before removal.

5-1.3.6 A CNG cylinder shall not be charged in excess of its maximum allowable working pressure at the normal temperature for that cylinder.

5-1.3.7 The transfer of CNG into the fuel supply container of a truck shall be performed by a person who is qualified by virtue of having performed the transfer operation for at least three full cycles under supervision and who has competence in initiating emergency procedures. This person shall be responsible for verifying the working pressure and for ensuring that the container is retested according to the required schedule.

5-1.3.8 A match or open flame shall not be used to check for leaks in CNG fuel systems.

5-1.3.9 Containers.

5-1.3.9.1 Containers and their appurtenances, piping systems, compression equipment, controls, devices, and pressure relief valves shall be maintained in proper operating condition.

5-1.3.9.2 To keep pressure relief devices in reliable operating condition, care shall be taken in the handling and storing of compressed natural gas containers to avoid damage. Care also shall be exercised to avoid plugging caused by paint or other dirt accumulation in pressure relief device channels or other parts that could interfere with the functioning of the device. Only qualified personnel shall be permitted to service pressure relief devices.

5-1.3.9.3 Only assemblies or original manufacturer's parts shall be used in the repair of pressure relief devices.

Exception: Assemblies or parts that have been proved by suitable testing.

5-1.3.10 CNG-powered vehicles shall not be parked near sources of heat, open flames, or similar sources of ignition.

5-1.3.11 The service valve of the fuel container shall be closed whenever vehicles are parked overnight or stored indoors for a protracted time.

5-2 Dual Fuel.

5-2.1*

Where operating a dual-fuel truck on CNG or LP-Gas, the gasoline level in the liquid fuel tank shall be checked daily. The truck shall not be operated unless the gasoline fuel tank is at least $^{1}/_{4}$ full.

5-2.2

Where operating a dual-fuel truck on CNG fuel, the provisions of 5-1.3 shall apply.

5-2.3

Where operating a dual-fuel truck on LP-Gas, the provisions of 5-1.2 shall apply.

5-2.4

Where operating a dual-fuel truck on liquid fuel, the provisions of 5-1.1 shall apply.

5-3 Changing and Charging Storage Batteries.

5-3.1

This section shall apply to batteries used on electric trucks. The two types of batteries commonly used are lead and nickel-iron. They contain corrosive chemical solutions, either acid or alkali, and, therefore, present a chemical hazard. While being charged, they give off hydrogen and oxygen, which, in certain concentrations, are explosive.

5-3.2

Battery-charging installations shall be located in areas designated for that purpose; such areas shall be kept free of extraneous combustible materials. Facilities shall be provided for the following:

(a) Flushing spilled electrolyte;

(b) Fire protection;

(c) Protecting charging apparatus from damage by trucks; and

(d) Adequate ventilation for dispersal of fumes from gassing batteries.

Where on-board chargers are used, charging shall be accomplished at locations designated for that purpose, taking into account the electrical requirements of the charger and facilities for fire protection.

Exception: Flushing facilities shall not be required if charging is accomplished without removing the battery from the vehicle.

5-3.3

Where handling acid concentrates greater than 50 percent acid (above 1.400 specific gravity), an eye-wash fountain shall be provided.

5-3.4

A conveyor, overhead hoist, or equivalent material-handling equipment shall be provided for handling batteries.

5-3.5

Chain hoists shall be equipped with load-chain containers. Where a hand hoist is used, uncovered batteries shall be covered with a sheet of plywood or other nonconducting material to prevent the hand chain from shorting on cell connectors or terminals. A properly insulated spreader bar shall be used with any overhead hoist.

5-3.6

Reinstalled or new batteries shall meet or exceed the battery type marked on the truck. Reinstalled batteries shall be positioned properly and secured in the truck.

5-3.7

A carboy tilter or siphon shall be provided where acid in carboys is used. Where diluting concentrated sulfuric acid to make up electrolyte, the acid ALWAYS shall be added to the water — not the reverse. Battery maintenance personnel shall wear protective clothing such as eye protection, long sleeves, and gloves.

Exception: Removal and replacement of batteries shall not require the use of protective clothing.

5-3.8

Electrical installations shall be in accordance with NFPA 70, *National Electrical Code*, and any local ordinances.

5-3.9

Trained and authorized personnel shall change or charge batteries.

5-3.10

Trucks shall be positioned properly and brakes shall be applied before attempting to change or charge batteries.

5-3.11

Where charging batteries, the vent caps shall be kept in place to avoid electrolyte spray. Care shall be taken to ensure that vent caps are functioning. The battery (or compartment) cover(s) shall be open to dissipate heat and gas.

5-3.12

Smoking shall be prohibited in the charging area.

5-3.13

Precautions shall be taken to prevent open flames, sparks, or electric arcs in battery-charging areas.

5-3.14

Tools and other metallic objects shall be kept away from the tops of uncovered batteries.

5-4 Use of Trucks in Classified Areas.

5-4.1

Industrial trucks shall not be used in classified areas.

Exception: Where specified in Chapter 1.

5-4.2 Markings of Types CNS, DS, DY, DX, ES, EE, EX, GS, LPS, GS/CNS, and GS/LPS Industrial Trucks and Their Areas of Use.

5-4.2.1 Proper equipment shall be used in classified areas for the safety and protection of employees and property. Approved trucks, listed by a testing laboratory for use in such areas, shall be clearly identified. To facilitate identification by operators and supervisory personnel, a uniform system of marking has been developed and is described in 5-4.2.2 and 5-4.2.3.

5-4.2.2 Durable markers indicating the designation of the type of truck for use in classified areas shall be applied to each side of the vehicle in a visible but protected location. These markers shall be distinctive in shape as shown in Figure 5-4.2.2. The markers for LPS, GS, DS, ES, CNS, GS/LPS, and GS/CNS shall measure 4 in. (102 mm) square markers. The width of the other markers shall be 5 in. (127 mm). The signs shall have black borders and lettering on a yellow background.

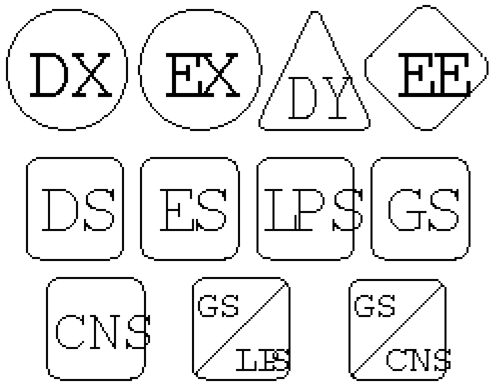


Figure 5-4.2.2. Markers used to identify type of industrial truck.

5-4.2.3 Entrances to classified areas where industrial trucks are to be used shall be posted with durable markers as shown in Figure 5-4.2.3. The minimum width of the sign shall be 11 in. (279 mm); the minimum height of the sign shall be 16 in. (406 mm). The sign shall have the word "caution" in yellow letters on a black background. The body of the sign shall have black letters on a yellow background. A marker(s) identical to that used on the side of the truck shall be installed on the sign as indicated. (*See Figure 5-4.2.2*.)

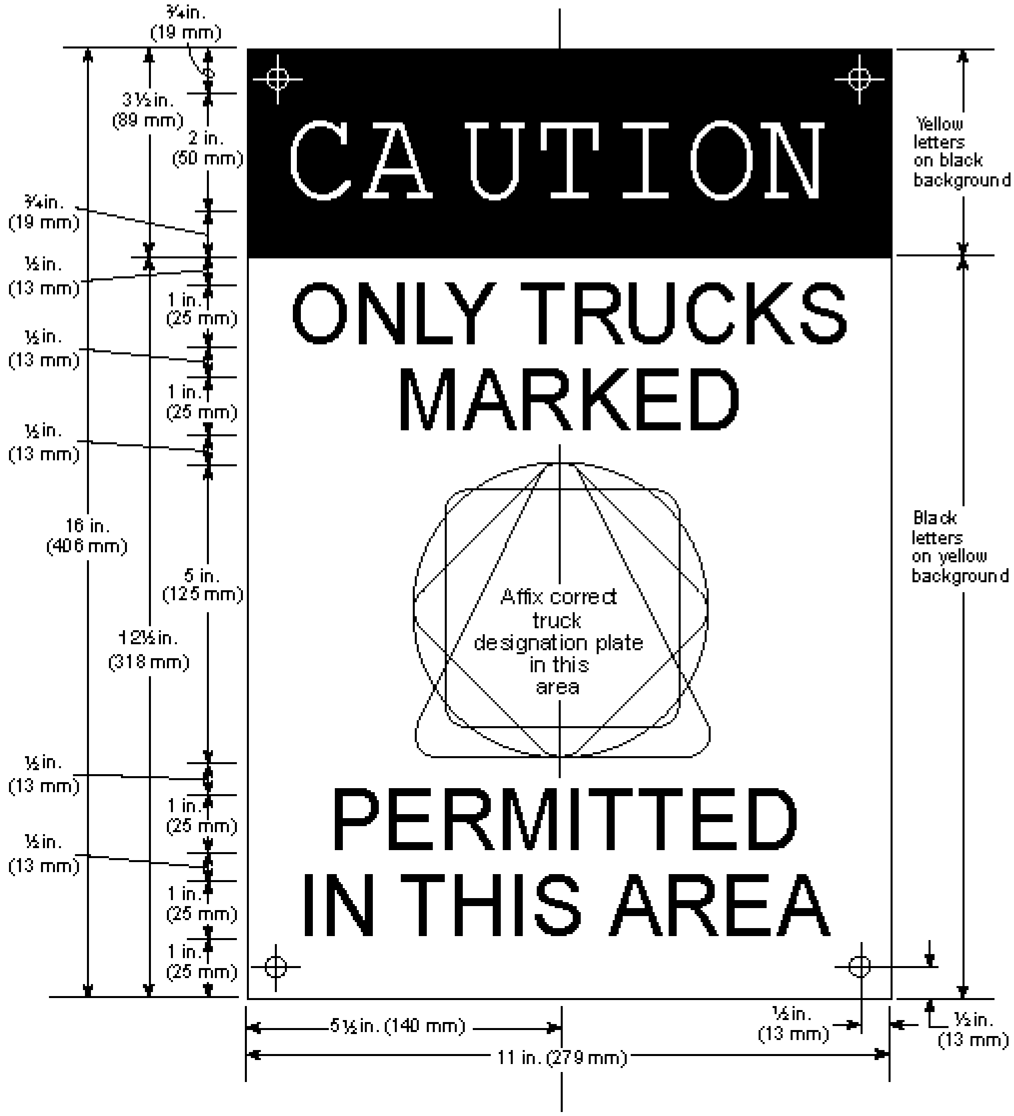


Figure 5-4.2.3. Building signs for posting at entrance to hazardous areas.

5-5 Safe Operating Rules.

Powered industrial truck operation shall be in accordance with ANSI B56.1, *Safety Standard for Low Lift and High Lift Trucks*.

5-6 Operating Procedures and Training.

5-6.1

There shall be a written operating procedure plan and operator training.

5-6.2

The procedure shall include, as a minimum, (a) through (e) as follows:

(a) Operation limited to trained personnel;

(b) Cautions where checking or filling tank;

(c) Action for suspected leak;

(d) Refueling instructions;

(e) Emergency items:

1. Shut off fuel valve;

2. Ensure battery correct type and position.

Chapter 6 Referenced Publications

6-1

The following documents or portions thereof are referenced within this standard and shall be considered part of the requirements of this document. The edition indicated for each reference is the current edition as of the date of the NFPA issuance of this document.

6-1.1 NFPA Publications.

National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.

NFPA 30, *Flammable and Combustible Liquids Code*, 1996 edition.

NFPA 30A, *Automotive and Marine Service Station Code*, 1996 edition.

NFPA 52, *Standard for Compressed Natural Gas (CNG) Vehicular Fuel Systems*, 1995 edition.

NFPA 58, *Standard for the Storage and Handling of Liquefied Petroleum Gases*, 1995 edition.

NFPA 70, *National Electrical Code*, 1996 edition.

6-1.2 Other Publications.

6-1.2.1 ASME Publication. American Society of Mechanical Engineers, 345 East 47th Street, New York, NY 10017.

ANSI/ASME B56.1, *Safety Standard for Low Lift and High Lift Trucks*, 1993.

6-1.2.2 ASTM Publication. American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103.

ASTM D 3175, *Standard Test Method for Volatile Matter in the Analysis Sample of Coal and Coke*, 1989.

6-1.2.3 UL Publications. Underwriters Laboratories Inc., 333 Pfingsten Road, Northbrook, IL 60062.

UL 558, *Standard for Safety Industrial Trucks, Internal Combustion Engine-Powered*, 1991.

UL 583, *Standard for Safety Electric-Battery-Powered Industrial Trucks*, 1991.

Appendix A Explanatory Material

This Appendix is not a part of the requirements of this NFPA document but is included for informational purposes only.

A-1-4 Approved. The National Fire Protection Association does not approve, inspect, or certify any installations, procedures, equipment, or materials; nor does it approve or evaluate testing laboratories. In determining the acceptability of installations, procedures, equipment, or materials, the authority having jurisdiction may base acceptance on compliance with NFPA or other appropriate standards. In the absence of such standards, said authority may require evidence of proper installation, procedure, or use. The authority having jurisdiction may also refer to the listings or labeling practices of an organization concerned with product evaluations that is in a position to determine compliance with appropriate standards for the current production of listed items.

A-1-4 Authority Having Jurisdiction. The phrase "authority having jurisdiction" is used in NFPA documents in a broad manner, since jurisdictions and approval agencies vary, as do their responsibilities. Where public safety is primary, the authority having jurisdiction may be a federal, state, local, or other regional department or individual such as a fire chief; fire marshal; chief of a fire prevention bureau, labor department, or health department; building official; electrical inspector; or others having statutory authority. For insurance purposes, an insurance inspection department, rating bureau, or other insurance company representative may be the authority having jurisdiction. In many circumstances, the property owner or his or her designated agent assumes the role of the authority having jurisdiction; at government installations, the commanding officer or departmental official may be the authority having jurisdiction.

A-1-4 Listed. The means for identifying listed equipment may vary for each organization concerned with product evaluation, some of which do not recognize equipment as listed unless it is also labeled. The authority having jurisdiction should utilize the system employed by the listing organization to identify a listed product.

A-1-4 Type Designation. Specific standards covering the types of industrial trucks detailed in Section 1-4 have been published by Underwriters Laboratories Inc., and are identified as UL 558, *Standard for Safety Industrial Trucks, Internal Combustion Engine-Powered*, and UL 583, *Standard for Safety Electric-Battery-Powered Industrial Trucks*. UL 558 covers Types D, DS, DY, G, GS, LP, LPS, G/LP and GS/LPS; UL 583 covers Types E, EE, ES, and EX.

Standards for Types CN, CNS, G/CN, and GS/CNS trucks are not in published form; however, information is available from Underwriters Laboratories Inc. regarding their requirements for these type designations.

The Underwriters Laboratories Inc. examination of powered industrial trucks relates to fire hazards only for Types D, DS, DY, G, GS, LP, LPS, G/LP, and GS/LPS internal-combustion-engine-powered industrial trucks; to fire and explosion hazard for Type DX trucks; to fire and electrical shock hazard only for Types E, ES, and EE battery-powered industrial trucks; and to the fire, electric shock, and explosion hazard for Type EX trucks suitable either for use in Class I, Group D, or Class II, Group G, hazardous locations. Trucks that have been examined and classified as meeting the respective Underwriters Laboratories standards for the particular area of use are found in the UL *Automotive Burglary Protection Mechanical Equipment Directory*, except for Type EX trucks, which can be found in the UL *Hazardous Locations Equipment Directory*.

A-1-6.1 For examples of those chemicals for which mixtures of their vapors in air are classified as Class I, Group A, B, or C, see Section 500-3 of NFPA 70, *National Electrical Code*. The following are some examples of Class I, Groups A, B, and C chemicals:

acetaldehyde	ethylene oxide
acetylene	ethylenimine
acrolein (inhibited)	hydrogen
allyl alcohol	hydrogen cyanide
arsine	hydrogen sulfide
butadiene	manufactured gases con-
n-butyraldehyde	taining more than 30%
carbon monoxide	hydrogen (by volume)
crotonaldehyde	morpholine
cyclopropane	2-nitropropane
diethyl ether	propylene oxide
diethylamine	propylnitrate
epichlorohydrin	tetrahydrofuran
ethyl mercaptan	unsymmetrical dimethyl
ethyl sulfide	hydrazine (UDMH 1,
ethylene	1-dimethyl hydrazine)

A-1-6.2.1 For examples of those chemicals for which mixtures of their vapors in air are classified as Class I, Group D, see Section 500-3 of NFPA 70, *National Electrical Code*. The following are some examples of Class I, Group D chemicals:

acetic acid (glacial)	ethanol (ethyl alcohol)
acetone	ethyl acetate
acrylonitrile	ethyl acrylate

ammonia	ethylene diamine
benzene	(anhydrous)
butane	ethylene dichloride
1-butanol	ethylene glycol mono-
2-butanol (secondary	methyl ether
utyl alcohol)	gasoline
n-butyl acetate	heptanes
isobutyl acetate	hexanes
sec-butyl alcohol	isoprene
di-isobutylene	isopropyl ether
ethane	mesityl oxide
methane (natural gas)	pentanes
methanol (methyl	1-pentanol (amyl
alcohol)	alcohol)
3-methyl-l-butanol	propane
(isoamyl alcohol)	1-propanol (propyl
methyl ethyl ketone	alcohol)
methyl isobutyl ketone	2-propanol (isopropyl
2-methyl-l-propanol	alcohol)
(isobutyl alcohol)	propylene
NFPA 702-methyl-2-propanol	styrene
(tertiary butyl alcohol)	toluene
petroleum naphtha	vinyl acetate
pyridine	vinyl chloride
octanes	xylenes

A-1-6.5.3 Most Group F dusts are electrically nonconductive and have resistivities in the range of 10^5 ohm-cm to 10^8 ohm-cm. However, some western (e.g., Wyoming) coals can have resistivities less than 10^5 ohm-cm.

A-1-6.8.1 Where these materials are either in enclosed systems or where flyings in air are minimized through use of ventilation controls, the use of Types CNS, DS, ES, GS, LPS, GS/CNS, or GS/LPS trucks may be considered.

A-2-2.5 The purpose of this requirement is to ensure the carburetor float system is functioning properly after a period of disuse.

A-3-1 Section 3-1 provides that acceptance of an industrial truck that has been converted rests entirely with the inspection authority having jurisdiction. The responsibility of determining whether or not a truck has been properly converted is placed with the authority having jurisdiction because it is impractical to ship each converted truck back to the testing laboratory to be reexamined or retested, and it is also impractical for the laboratory to send a representative into the field to examine or test every converted truck.

It is recognized that the various authorities having jurisdiction may not be expert in determining what constitutes a proper conversion. Installation directions furnished with conversion equipment, "Listed by Report," specify in detail how the conversion is to be made so that it will be in accordance with NFPA 58, *Standard for the Storage and Handling of Liquefied Petroleum Gases*. These detailed instructions supply the authority having jurisdiction with all the necessary information to determine whether or not a truck has been properly converted.

A-5-1.1.2 Safe outdoor locations are preferable to those indoors. NFPA 30, *Flammable and Combustible Liquids Code*, includes requirements for arranging indoor fueling facilities. NFPA 30A, *Automotive and Marine Service Station Code*, includes requirements for arranging outdoor fueling facilities.

A-5-1.2.10 The exchange of removable LP-Gas containers is preferably done outdoors, but may be done indoors.

A-5-2.1

The purpose in requiring that the liquid fuel tank always be filled with gasoline to at least the $^{1}/_{4}$-full level is to provide a sufficient amount of liquid fuel to maintain a vapor saturation in the tank above the normally explosive level. The amount of fuel in the tank can be determined using the fuel gauge provided on the vehicle.

Appendix B Referenced Publications

B-1 The following documents or portions thereof are referenced within this standard for informational purposes only and thus are not considered part of the requirements of this document. The edition indicated for each reference is the current edition as of the date of the NFPA issuance of this document.

B-1.1 NFPA Publications. National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.

NFPA 30, *Flammable and Combustible Liquids Code*, 1996 edition.

NFPA 30A, *Automotive and Marine Service Station Code*, 1996 edition.

NFPA 52, *Standard for Compressed Natural Gas (CNG) Vehicular Fuel Systems*, 1995 edition.NFPA 52

NFPA 58, *Standard for the Storage and Handling of Liquefied Petroleum Gases*, 1995 edition.

NFPA 70, *National Electrical Code*, 1996 edition.

B-1.2 Other Publications.

B-1.2.1 UL Publications. Underwriters Laboratories Inc., 333 Pfingsten Road, Northbrook, IL 60062.

UL 558, *Standard for Safety Industrial Trucks, Internal Combustion Engine-Powered*, 1991.

UL 583, *Standard for Safety Electric-Battery-Powered Industrial Trucks*, 1991.

Automotive Burglary Protection Mechanical Equipment Directory, 1994.

Hazardous Locations Equipment Directory, 1995.

NFPA 512

1994 Edition

Standard for Truck Fire Protection

1994 Edition

This edition of NFPA 512, *Standard for Truck Fire Protection*, was prepared by the Technical Committee on Motor Vehicle and Highway Fire Protection and acted on by the National Fire Protection Association, Inc. at its Fall Meeting held November 15-18, 1993, in Phoenix, AZ. It was issued by the Standards Council on January 14, 1994, with an effective date of February 11, 1994, and supersedes all previous editions.

The 1994 edition of this document has been approved by the American National Standards Institute.

Changes other than editorial are indicated by a vertical rule in the margin of the pages on which they appear. These lines are included as an aid to the user in identifying changes from the previous edition.

Origin and Development of NFPA 512

The first edition of the Recommended Good Practices was drafted by the NFPA Committee on Truck Fire Protection and adopted by the Association in 1952. Amendments were adopted in 1955. In 1967 the Committee was reorganized as the Committee on Motor Vehicle and Highway Fire Protection. The scope of the Committee was greatly expanded at the time of the reorganization. The reorganized Committee undertook as its first order of business a thorough review of the 1955 edition of NFPA 512.

The 1970 edition was a complete revision and reorganization of the 1955 edition. The 1975 standard was a complete revision of the 1970 Recommended Good Practices. The 1975 edition was partially revised in 1978, and the 1984 edition represented further partial revision to that 1978 edition. Minor changes were made in the 1990 edition in emergency signals (fusees) and fire protection requirements to bring the standard into conformity with the Federal Motor Carrier Safety Regulations.

Minor changes in the 1994 edition were made to comply with the NFPA *Manual of Style*. Also, revised appendix notes were added addressing the scope and portable extinguishers.

Technical Committee on Motor Vehicle and Highway Fire Protection

Enoch Lipson, *Chair*
The Port Authority of NY & NJ, NY

Neill Darmstadter, American Trucking Assn., Inc., VA

A. L. Elliott, Sacramento, CA

William A. Eppich, The Protectowire Co., Inc., MA

Clifford J. Harvison, Nat'l Tank Truck Carriers, Inc., VA

Marice M. Pilette, Mechanical Designs Ltd., MA

George E. Ralph, Southport, ME

Steven R. Shinners, Yellow Freight System, Inc., KS

Michael P. Wilson, American Insurance Services Group, Inc., NY

Alternates

Arthur G. Bendelius, Parsons Brinckerhoff, NY
(Alt. to A. L. Elliott)

Raymond D. Scanlon, The Port Authority of NY & NJ, NY
(Alt. to E. Lipson)

Richard Ortisi-Best, NFPA Staff Liaison

This list represents the membership at the time the Committee was balloted on the text of this edition. Since that time, changes in the membership may have occurred.

NOTE: Membership on a Committee shall not in and of itself constitute an endorsement of the Association or any document developed by the Committee on which the member serves.

Committee Scope: This Committee has primary responsibility for documents on motor vehicle fire prevention and protection measures to reduce loss of life and property damage in the operation and maintenance (repair) of such vehicles (except as specified herein); fire prevention and protection recommendations for motor freight terminals; protection for tunnels, air-right structures, and bridges; and to recommend protection facilities on limited-access highways. Included as motor vehicles are trucks, buses, taxicabs, limousines, and passenger cars; excluded are the design, fire protection, and operational procedures for fire apparatus, mobile homes and travel trailers, tank vehicles of all kinds for handling flammable and combustible liquids and liquefied petroleum gases, and vehicles transporting explosives and other hazardous chemicals. The construction and protection of garages is handled by the NFPA Committee on Garages.

NFPA 512

Standard for Truck Fire Protection

1994 Edition

NOTE: An asterisk (*) following the number or letter designating a paragraph indicates explanatory material on that paragraph in Appendix A.
Information on referenced publications can be found in Chapter 5 and Appendix B.

Chapter 1 Introduction

1-1* Scope.

This standard prescribes fire protection measures for property-carrying motor vehicles. The requirements given herein are minimum. They reflect the fact that motor vehicles are an indispensable major segment of the property-carrying transportation system, and, therefore, fires involving these vehicles can have a serious impact on public safety and the delivery and conservation of critical merchandise.

Exception No. 1: Aircraft fuel servicing vehicles; covered in NFPA 407, Standard for Aircraft Fuel Servicing.

Exception No. 2: Vehicles transporting explosives and blasting agents; covered in NFPA 495, Explosive Materials Code.

Exception No. 3: Tank vehicles for flammable and combustible liquids; covered in NFPA 385, Standard for Tank Vehicles for Flammable and Combustible Liquids.

Exception No. 4: LP-Gas tank vehicles and vehicles transporting portable LP-Gas containers; covered in NFPA 58, Standard for the Storage and Handling of Liquefied Petroleum Gases.

Exception No. 5: Motor vehicles subject to the regulations of the U.S. Department of Transportation.

1-2 Purpose.

This standard is for the use and guidance of persons charged with operating and maintaining property-carrying motor vehicles to provide that degree of public safety from fires involving such equipment that can be reasonably required. Consideration has been given to the fact that motor vehicles, by their very nature, can expose lives and property to unexpected fires, and that many roads, particularly limited-access highways, make it difficult for organized fire-fighting agencies to reach the scene of an emergency quickly.

1-3 Definitions.

Approved. Acceptable to the authority having jurisdiction.

NOTE: The National Fire Protection Association does not approve, inspect, or certify any installations, procedures, equipment, or materials; nor does it approve or evaluate testing laboratories. In determining the acceptability of installations, procedures, equipment, or materials, the authority having jurisdiction may base acceptance on compliance with NFPA or other appropriate standards. In the absence of such standards, said authority may require evidence of proper installation, procedure, or use. The authority having jurisdiction may also refer to the listings or labeling practices of an organization concerned with product evaluations that is in a position to determine compliance with appropriate standards for the current production of listed items.

Authority Having Jurisdiction. The organization, office, or individual responsible for approving equipment, an installation, or a procedure.

NOTE: The phrase “authority having jurisdiction” is used in NFPA documents in a broad manner, since jurisdictions and approval agencies vary, as do their responsibilities. Where public safety is primary, the authority having jurisdiction may be a federal, state, local, or other regional department or individual such as a fire chief; fire marshal; chief of a fire prevention bureau, labor department, or health department; building official; electrical inspector; or others having statutory authority. For insurance purposes, an insurance inspection department, rating bureau, or other insurance company representative may be the authority having jurisdiction. In many circumstances, the property owner or his or her designated agent assumes the role of the authority having jurisdiction; at government installations, the commanding officer or departmental official may be the authority having jurisdiction.

Cargo Space. Includes the open, partially or fully enclosed, space of any motor vehicle used for carrying cargo.

General Cargo. Includes everything except materials specifically described and known as hazardous materials.

Hazardous Material. A substance or material that has been determined by the Secretary of Transportation to be capable of posing an unreasonable risk to health, safety, and property when transported in commerce, and that has been so designated in U.S. Department of Transportation Regulations 49 CFR, Parts 100-199.

Labeled. Equipment or materials to which has been attached a label, symbol, or other identifying mark of an organization that is acceptable to the authority having jurisdiction and concerned with product evaluation that maintains periodic inspection of production of labeled equipment or materials and by whose labeling the manufacturer indicates compliance with appropriate standards or performance in a specified manner.

Listed. Equipment or materials included in a list published by an organization acceptable to the authority having jurisdiction and concerned with product evaluation that maintains periodic inspection of production of listed equipment or materials and whose listing states either that the equipment or material meets appropriate standards or has been tested and found suitable for use in a specified manner.

NOTE: The means for identifying listed equipment may vary for each organization concerned with product evaluation, some of which do not recognize equipment as listed unless it is also labeled. The authority having jurisdiction should utilize the system employed by the listing organization to identify a listed product.

Motor Vehicle. Any self-propelled truck or truck tractor, or any semitrailer or full trailer drawn by another motor vehicle.

Shall. Indicates a mandatory requirement.

Chapter 2 Fire Prevention — Cargoes

2-1* General.

General cargo shall be loaded so that it does not constitute a fire hazard to other materials in transit or to the vehicle.

2-2 Hazardous.

Hazardous materials shall be packaged, loaded, and transported in accordance with U.S. Department of Transportation Regulations 49 CFR, Parts 100-199.

Chapter 3* Fire Prevention — Vehicle and Equipment

3-1 General.

The driver shall satisfy himself or herself before a trip that at least the following are in safe operating condition:

(a) Service brakes, including trailer brake connections,

(b) Parking (hand) brake,

(c) Steering mechanism,

(d) Lighting devices and reflectors,

(e) Horn,

(f) Coupling devices,

(g) Tires,

(h) Windshield wipers,

(i) Rear view mirrors,

(j) Emergency warning devices,

(k) Fire extinguishers.

3-2 Fueling.

3-2.1

All engines and motors shall be stopped during fueling operations, all open flames extinguished, and “no smoking” in the immediate area enforced. Fuel tanks shall not be overfilled, and allowance shall be made for expansion due to a rise in temperature to prevent spillage. The nozzle of the fueling hose shall be kept in continuous contact with the fuel tank intake pipe to prevent sparking from accumulated static electricity.

3-2.2

All fuel supplies for propulsion of the vehicle or any accessory equipment shall be carried in properly mounted tanks.

3-2.3

Where liquefied petroleum gases are used as fuel, NFPA 58, *Standard for the Storage and Handling of Liquefied Petroleum Gases*, shall be followed.

3-3* Tires.

The procedures of 3-3.1 through 3-3.4 shall be observed to minimize the occurrence of tire fires.

3-3.1

Tires shall be inflated to the proper pressure. Air pressure shall not be reduced ("bled") en route.

3-3.2

Dual tires shall be properly mated and properly spaced between pairs. Valve stems shall not be in contact with brake drums.

3-3.3

The driver shall examine the vehicle's tires at the beginning of each trip and each time the vehicle is parked. A driver transporting hazardous materials shall recheck the tires at least once every two hours or 100 miles of driving, whichever comes first.

3-3.4

In the event that a driver discovers an overheated tire, the driver shall stop immediately and cause it to be removed from the vehicle to a safe distance. The driver shall not drive the vehicle until the tire has been repaired or replaced. The tire that has been found overheated shall not be put in any location on the vehicle until cool to the touch.

3-4* Emergency Signals (Fusees).

3-4.1

Fusees shall be stored in open racks or metal boxes used for no other purpose in the cab or other readily accessible place on the vehicle.

3-4.2

Fusees shall not be attached to any part of the motor vehicle.

3-4.3

Fusees shall not be used in close proximity to leaking or spilled flammable liquid or leaking flammable gas.

3-4.4

The use of flame-producing warning signals shall be prohibited on vehicles transporting Class A or B explosives, on vehicles transporting flammable liquids or gases in cargo tanks, and on vehicles using compressed gas as a motor fuel.

3-5* Heaters.

3-5.1 Prohibited Types of Heaters.

The installation or use of the following types of heaters shall be prohibited:

3-5.1.1 Unenclosed Flame Heaters. Any type of heater employing a flame that is not fully enclosed (other than for small combustion air openings).

Exception: Open flame heaters shall be permitted for the heating of cargo tanks, but shall not be in operation while the vehicle is in motion.

3-5.1.2 Heaters Permitting Fuel Leakage. Any type of heater from the burner of which there could be spillage or leakage of fuel upon the tilting or overturning of the vehicle.

3-5.1.3 Solid Fuel Heaters. Any stove or other heater employing solid fuel, except wood charcoal.

3-5.2 Heater Specifications.

All heaters shall comply with the specifications of 3-5.2.1 through 3-5.2.10.

3-5.2.1 Protection of Heating Elements. Every heater shall be located or protected to prevent contact therewith by cargo or by occupants, unless the surface temperature of the protecting grilles or of any exposed portions of the heaters, inclusive of exhaust stacks, pipes, or conduits, is lower than would cause contact burns. Adequate protection shall be afforded against igniting parts of the vehicle or cargo, or against burning occupants by direct radiation. Wood charcoal heaters shall be enclosed within a metal barrel, drum, or similar protective enclosure with a securely fastened cover.

3-5.2.2 Securing of Heaters. Every heater and every heater enclosure shall be securely fastened to the vehicle in a substantial manner to provide against relative motion within the vehicle during normal usage or in the event the vehicle overturns. Every heater shall be designed, constructed, and mounted to minimize the likelihood of disassembly of any of its parts, including exhaust stack, pipes, or conduits, upon overturn of the vehicle in or on which it is mounted. Wood charcoal heaters shall be secured within the enclosure specified in 3-5.2.1, and the enclosure shall be securely fastened to the motor vehicle.

3-5.2.3 Fuel Lines. Where, either in normal operation or in the event of overturn or collision, there is likely to be relative motion between the fuel tank for a heater and the heater, or between either of such units and the fuel lines between them, a suitable means shall be provided to allow this motion without causing failure of the fuel lines.

3-5.2.4 Hot Water and Steam Hoses. Hoses for all hot water and steam heater systems shall be suitable for the purpose.

3-5.2.5 Electrical Apparatus. Every heater employing any electrical apparatus shall be equipped with electrical conductors, switches, connectors, and other electrical parts of ample rating to provide against overheating. Any electric motor employed in any heater shall be of adequate size and located so that it will not be overheated. Electrical circuits shall be provided with fuses or circuit breakers to prevent electrical overloading. All electrical conductors employed in or leading to any heater shall be secured against dangling, chafing, and rubbing, and shall have suitable protection against any other condition likely to produce short or open circuits. If a separate storage battery is located within the cargo space, such battery shall be securely mounted and equipped with nonspill filler caps.

Electrical equipment listed as suited for the foregoing use by a recognized laboratory shall be deemed to comply with the foregoing requirements, except as to security against dangling, etc.

3-5.2.6 Combustion Air. Heaters shall be constructed and installed to ensure sufficient outside air supply for normal combustion.

3-5.2.7 Combustion Heater Exhaust Construction. Every heater employing the combustion of fuel oil, gasoline, liquefied petroleum gas, or any other combustible materials shall be provided with substantial means of conducting the products of combustion to the outside of the vehicle.

Exception: This requirement shall not apply to heaters used solely to heat the cargo space. Such unvented heaters shall be removed during loading and unloading operations.

The exhaust pipe, stack, or conduit, if required, shall be sufficiently substantial and secured to provide assurance against leakage or discharge of products of combustion within the vehicle, and, if necessary, shall be insulated to make unlikely the burning or charring of parts of the vehicle by radiation or by direct contact. The place of discharge of the products of combustion to the atmosphere and the means of discharge of such products shall be such as to minimize the likelihood of their re-entry into the vehicle under all operating conditions.

3-5.2.8 Combustion Chamber Construction. The design and construction of any combustion-type heater shall provide against the leakage of products of combustion into air to be heated and circulated. The material employed in combustion chambers shall provide against leakage because of corrosion, oxidation, or other deterioration. Joints between combustion chambers and the air chambers with which they are in thermal and mechanical contact shall be designed and constructed to prevent leakage between the chambers; the materials employed in such joints shall have melting points substantially higher than the maximum temperatures likely to be attained at the joints.

Exception: Cargo space heaters permitted by 3-5.2.6 and unenclosed flame heaters used for heating the cargo of tank motor vehicles.

3-5.2.9 Automatic Fuel Control. Gravity or siphon feed shall not be used for heaters burning liquid fuels. Such heaters shall be equipped with automatic means for shutting off the fuel or for reducing such flow of fuel to the smallest practicable magnitude in the event of overturn of the vehicle. Heaters using liquefied petroleum gas or fuel shall have the fuel line equipped with automatic means at the source of supply for shutting off the fuel in the event of separation, breakage, or disconnection of any of the fuel lines between the supply source and the heater.

3-5.2.10 Shutoff Control. Automatic means, or manual means if the control is readily accessible to the driver without moving from the driver's seat, shall be provided to shut off the fuel and electrical supply in case of failure of the heater to function for any reason, or in case the heater should function improperly or overheat.

Exception: This requirement shall not apply to wood charcoal heaters or to heaters used solely to heat the contents of cargo tank motor vehicles, but wood charcoal heaters shall be provided with a controlled method of regulating the flow of combustion air.

3-5.2.11* The users of heaters in vehicles transporting hazardous materials shall comply with applicable regulations of the U.S. Department of Transportation, 49 CFR, Section 177.834 (1).

3-6 Lighting of Van Interiors.

If the interiors of closed vans are electrically lighted, the lights shall be protected by screens or grilles to prevent contact of the bulb by cargo.

3-7 Refrigeration Equipment.

3-7.1

Refrigeration machinery and equipment shall be installed so as not to constitute a fire hazard to cargo or vehicle.

3-7.2

The fuel supply for refrigeration equipment shall be adequate to permit operation between normal refueling points to avoid the need to refuel with makeshift devices while on the road. Extra fuel, if carried, shall be stored in approved-type storage tanks affixed to the vehicle. The transfer of fuel to the refrigeration units shall be by a safely arranged small hand pump unless the equipment's design permits direct suction from the fuel storage tank.

3-7.3

Refueling of refrigeration equipment shall be conducted at standard fueling stations utilizing approved-type facilities.

Chapter 4 Fire Protection

4-1 Emergency Procedures.

4-1.1*

The driver, on discovery of a fire, shall move the vehicle to the side of the road to a point where other equipment and property are not endangered. Where feasible, vehicles of a combination should be uncoupled and separated, if this can be done without endangering the safety of the driver.

4-1.2

An immediate notification shall be given by the fastest means practicable to the nearest fire emergency service. The driver shall advise fire fighters or other emergency responders of the nature of the cargo. If the cargo includes hazardous materials, the driver should have the shipping papers available immediately for examination by first-responders.

4-1.3

In case of danger that a fire might spread out of control, particularly with vehicles transporting hazardous materials, the driver shall take steps to warn the public away from the scene and inform the fire emergency service of the nature of the cargo.

4-2* Fire Extinguishers.

4-2.1*

Each power unit shall be equipped with at least one fire extinguisher, in accordance with NFPA 10, *Standard for Portable Fire Extinguishers*, that is properly filled and located so that it is readily accessible in case of a fire emergency. Every such extinguisher shall be designed, constructed, and maintained to permit visual determination of whether it is fully charged. Extinguishers shall be suitable for use at temperatures as low as –40°F (–40°C) without additional protection.

4-2.2* Type and Size.

4-2.2.1 A power unit used to transport hazardous materials shall be equipped with a fire extinguisher having a listed rating of 10B:C or higher.

4-2.2.2 A power unit used to transport general cargo shall be equipped with a fire extinguisher having a listed rating of 5B:C or higher, or two fire extinguishers, each of which has a listed rating of at least 4B:C.

4-2.2.3 The extinguisher rating appears on the extinguisher instruction plate. Extinguishers lacking such instruction plates shall be prohibited.

4-2.2.4 Carbon tetrachloride and methyl bromide agents shall not be used.

4-2.3 Mounting.

Extinguishers shall be securely mounted and readily accessible. If the extinguisher is in a location other than within the driver's compartment, its location should be indicated by appropriate markings on the exterior of the vehicle.

Chapter 5 Referenced Publications

5-1

The following documents or portions thereof are referenced within this standard and shall be considered part of the requirements of this document. The edition indicated for each reference is the current edition as of the date of the NFPA issuance of this document.

5-1.1 NFPA Publications.

National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.

NFPA 10, *Standard for Portable Fire Extinguishers*, 1990 edition.

NFPA 58, *Standard for the Storage and Handling of Liquefied Petroleum Gases,* 1992 edition.

5-1.2 Other Publication.

5-1.2.1 U.S. Department of Transportation, 400 7th Street, SW, Washington, DC 20590.

Code of Federal Regulations, 49 CFR, Parts 100-199, as amended.

Appendix A Explanatory Material

This Appendix is not a part of the requirements of this NFPA document, but is included for informational purposes only.

A-1-1 Scope.

Commercial vehicles operating in interstate or foreign commerce are subject to the fire protection provisions of the Federal Motor Carrier Safety Regulations (FMCSR) administered by the U.S. Department of Transportation, 49 CFR, Parts 383-399. These requirements are incorporated within this standard because they represent minimum fire safety requirements that must be met by all persons responsible for the operation of such vehicles.

The transportation of hazardous materials in both interstate, foreign, and intrastate commerce is subject to the Hazardous Materials Regulations (HMR) of the U.S. Department of Transportation, 49 CFR, Parts 100-199.

Through participation in the federally funded Motor Carrier Safety Assistance Program (MCSAP), virtually all states have now adopted by reference the federal regulations cited above. These regulations are being jointly enforced by authorized federal, state, and local enforcement personnel at roadside checks of vehicles and drivers, and through inspections at motor carrier facilities.

A-2-1 Fire Prevention — Cargoes.

Fiber materials, that is, excelsior, rags, cotton waste, waste paper, paper shreddings, etc., should be transported in an enclosed vehicle or with a fire-retardant tarpaulin covering on all sides to avoid accidental ignition from external sources during transportation.

A-3 Fire Prevention — Vehicle and Equipment.

Fire prevention starts with proper vehicle maintenance and servicing operations, with particular emphasis on fueling of the vehicle and accessory equipment.

A-3-3 Tires.

Tire fires are caused by high internal tire temperatures that may result from overloading, underinflation, high speed, high road temperatures, and rubbing of dual tires. They are difficult to extinguish and are likely to rekindle. Tire fires are best extinguished by applying large quantities of water, where available, until the tire and wheel are cool to the touch. Putting the flame out is not enough as there may be burning inside the carcass. If quantities of water are not available and flames cannot be put out with the fire extinguishers, use dirt or sand and remove tires as quickly as possible.

A driver discovering a tire that is underinflated may drive at a moderate speed to the nearest place at which necessary service or repairs can be performed to correct the condition.

When touching tires to determine whether they are hot, use the back of the hand; touching with the palm often causes the fingers to close and could result in serious burns.

A-3-4 Flame-Producing Warning Devices.

Carriers using flame-producing warning signals (other than fusees) should replace such warning signals at the earliest opportunity with reflective triangles marked as being in compliance with Federal Motor Vehicle Safety Standard 125, 49 CFR, 571.125. Fusees may be permitted to be used to supplement these reflective triangles, and they may be permitted to be used by the driver to aid in the control of traffic in an emergency, provided they are not used in a manner that will increase the danger of fire.

A-3-5 Heaters.

The installation of heating equipment for protection of commodities from cold requires particular attention to minimize fire and other hazards.

A-3-5.2.11 Specific reference is made to 49 CFR, Parts 100-199, Section 177.834 (1).

A-4-1.1 Emergency Procedures.

Most fires start small and, if attacked quickly with appropriate extinguishing measures, can be handled by the driver. Large fires require the attention of trained fire fighters with ample equipment; fire fighters are also needed in case the original fire reignites after first aid extinguishing equipment is exhausted, particularly if tire fires are involved.

Consideration should be given to providing additional information to the driver attempting to deal with a small fire. This information might include:

(a) A warning that the driver should not risk his or her personal safety.

(b) A warning that the typical truck fire extinguisher will discharge in 8 to 10 seconds.

(c) A warning to fight a fire with the wind at the driver's back.

(d) A warning to the driver not to get surrounded by fire.

(e) An instruction to aim at the base of the flames and use a sweeping motion.

(f) A warning that, if fire is suspected within a closed van, the driver should not open the doors until there is adequate help to deal with the flare-up that is likely to occur when the doors are opened and oxygen reaches the fire.

A-4-2 Fire Extinguishers.

A motor vehicle needs protection against its own fire hazards regardless of the cargo. In some instances, this protection may be sufficient for the cargo as well; in others, particularly where flammable or combustible hazardous materials are involved, supplemental protection may be needed or specified by law.

A-4-2.1

By interpretation, the U.S. Department of Transportation considers an extinguisher to meet the requirement of being capable of visual inspection if:

(a) Equipped with a gauge that indicates charge pressure, or

(b) Charge pressure is maintained by a metallic seal that is readily accessible for inspection without the use of tools.

The following have been deemed not to meet the regulatory requirement for an extinguisher capable of visual inspection to determine whether it is properly charged:

(a) The use of a wire seal on the operating mechanism, or other device indicating only that the operating mechanism has not been manipulated, or

(b) An extinguisher that must be checked by weighing to determine that it is properly charged.

A-4-2.2 Ratings on Fire Extinguisher Labels.

The various extinguishing agents are not uniformly effective on the different classes of fires. UL 711, *Standard for Rating and Fire Testing of Fire Extinguishers*, was developed in order to rate the relative effectiveness of extinguishers. The Underwriters Laboratories rating system is based on using experts to extinguish scaled reproducible fires with extinguishers being tested for Class A (wood, paper, cloth, insulation, etc.) and Class B (flammable liquids, grease, etc.) fire extinguishing capability. The numerical prefix indicates relative potential, so that an extinguisher rated 10-B has twice the potential on Class B fires as one rated 5-B. Similarly, an extinguisher displaying a UL rating of 2-A has twice the potential on Class A fires as one rated 1-A. The C rating indicates that the extinguishing agent is electrically nonconductive and can be applied safely to energized electrical equipment without the possibility of a shock hazard. (The C rating does not have a numerical designation associated with it.)

Example: An extinguisher is rated and classified 4-A:20-B.C. This indicates the following:

1. It should extinguish approximately twice as much Class A fire as a 2-A [$2^1/_2$-gal (9.46-L) water] rated extinguisher.

2. It should extinguish approximately 20 times as much Class B fire as a 1-B rated extinguisher.

3. It is suitable for use on energized electrical equipment.

Fire extinguishers are also required to have a decal with use code symbols positioned below the operating instructions. The use code symbols reflect the rating of the extinguisher and are intended for quick reference by the user. Table A-4-2.2 depicts the current pictorial marking system. The absence of the Class A symbol in the third row of the table indicates that these extinguishers did not achieve the A rating but could be used on Class A fires with less effectiveness than those with the A rating. (Older extinguishers have decals with a triangle, square, circle, and 5-point star containing the letters A, B, C, and D, respectively.)

Before selecting a fire extinguisher, identify and know the hazard on which it may be used.

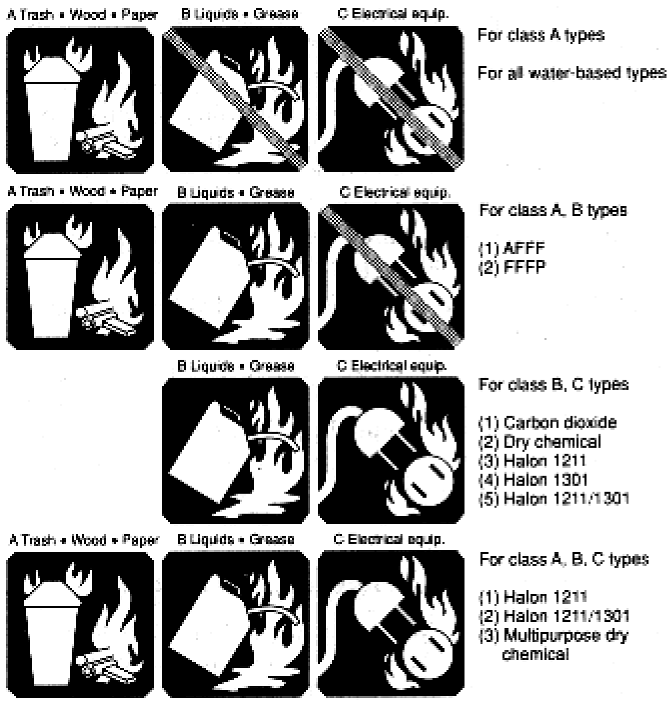
There are three ways to select a fire extinguisher:

(a) Select an extinguisher rated for Class A, B, and C fires.

(b) Select an extinguisher especially designed for a specific fire likely to occur.

(c) Select a combination of the two.

Table A-4-2.2 Typical Pictorial Extinguisher Marking Labels



Color Separation Identification (picture symbol objects are white; background borders are white)
- Blue — background for "YES" symbols
- Black — background for symbols with slash mark ("NO")
  — class of fire symbols and wording
- Red — slash mark for black background symbols

NOTE 1: A red slash through any symbol means the extinguisher should not be used on that class of fire.

NOTE 2: A missing symbol means that this extinguisher has not been rated for a given class of fire.

Appendix B Referenced Publications

B-1

The following documents or portions thereof are referenced within this standard for informational purposes only and thus are not considered part of the requirements of this document. The edition indicated for each reference is the current edition as of the date of the NFPA issuance of this document.

B-1.1 NFPA Publications.

National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.

NFPA 58, *Standard for the Storage and Handling of Liquefied Petroleum Gases,* 1992 edition.

NFPA 385, *Standard for Tank Vehicles for Flammable and Combustible Liquids*, 1990 edition.

NFPA 407, *Standard for Aircraft Fuel Servicing*, 1990 edition.

NFPA 495, *Explosive Materials Code*, 1992 edition.

B-1.2 Other Publications.

B-1.2.1 UL Publication. Underwriters Laboratories Inc., 333 Pfingsten Road, Northbrook, IL 60062.

ANSI/UL 711-1979, *Standard for Rating and Fire Testing Extinguishers.*

B-1.2.2 U.S. Department of Transportation Publications. U.S. Department of Transportation, 400 7th Street, SW, Washington, DC 20590.

Code of Federal Regulations, 49 CFR, Parts 100-199.

Code of Federal Regulations, 49 CFR, Parts 383-399.

Code of Federal Regulations, 49 CFR, Parts 390-399.

U.S. Department of Transportation Regulations, 49 CFR, Part 571.125, Federal Motor Vehicle Safety Standard 125, Warning Devices.

NFPA 513

1994 Edition

Standard for Motor Freight Terminals

1994 Edition

This edition of NFPA 513, *Standard for Motor Freight Terminals*, was prepared by the Technical Committee on Motor Vehicle and Highway Fire Protection and acted on by the National Fire Protection Association, Inc. at its Fall Meeting held November 15-18, 1993, in Phoenix, AZ. It was issued by the Standards Council on January 14, 1994, with an effective date of February 11, 1994, and supersedes all previous editions.

The 1994 edition of this document has been approved by the American National Standards Institute.

Changes other than editorial are indicated by a vertical rule in the margin of the pages on which they appear. These lines are included as an aid to the user in identifying changes from the previous edition.

Origin and Development of NFPA 513

The first edition of NFPA 513 was prepared by the NFPA Committee on Truck Transportation. It was tentatively adopted in 1958 and adopted by the Association as an official NFPA Standard in 1959. In 1967, the Committee was reorganized as the Committee on Motor Vehicle and Highway Fire Protection.

The 1973 edition was a complete revision and reorganization of the 1971 edition. The 1973 edition was partially revised in 1975, 1978, and 1984. The 1990 edition contained minor changes such as an update of Table 3-1.2, which is extracted from NFPA 30, *Flammable and Combustible Liquids Code*. Very minor changes were incorporated in Chapters 3 and 6 of this 1994 edition.

Technical Committee on Motor Vehicle and Highway Fire Protection

Enoch Lipson, *Chair*
The Port Authority of NY & NJ, NY

Neill Darmstadter, American Trucking Assn., Inc., VA

A. L. Elliott, Sacramento, CA

William A. Eppich, The Protectowire Co., Inc., MA

Clifford J. Harvison, Nat'l Tank Truck Carriers, Inc., VA

Marice M. Pilette, Mechanical Designs Ltd., MA

George E. Ralph, Southport, ME

Steven R. Shinners, Yellow Freight System, Inc., KS

Michael P. Wilson, American Insurance Services Group, Inc., NY

Alternates

Arthur G. Bendelius, Parsons Brinckerhoff, NY
(Alt. to A. L. Elliott)

Raymond D. Scanlon, The Port Authority of NY & NJ, NY
(Alt. to E. Lipson)

Richard Ortisi-Best, NFPA Staff Liaison

This list represents the membership at the time the Committee was balloted on the text of this edition. Since that time, changes in the membership may have occurred.

NOTE: Membership on a Committee shall not in and of itself constitute an endorsement of the

Association or any document developed by the Committee on which the member serves.

Committee Scope: This Committee shall have primary responsibility for documents on motor vehicle fire prevention and protection measures to reduce loss of life and property damage in the operation and maintenance (repair) of such vehicles (except as specified herein); fire prevention and protection recommendations for motor freight terminals; protection for tunnels, air-right structures, and bridges; and to recommend protection facilities on limited-access highways. Included as motor vehicles are trucks, buses, taxicabs, limousines, and passenger cars; excluded are the design, fire protection, and operational procedures for fire apparatus, mobile homes and travel trailers, tank vehicles of all kinds for handling flammable and combustible liquids and liquefied petroleum gases, and vehicles transporting explosives and other hazardous chemicals. The construction and protection of garages is handled by the NFPA Committee on Garages.

NFPA 513

Standard for Motor Freight Terminals

1994 Edition

NOTE: An asterisk (*) following the number or letter designating a paragraph indicates explanatory material on that paragraph in Appendix A.
Information on referenced publications can be found in Chapter 7 and Appendix B.

Chapter 1 General Information

1-1 Application and Scope.

1-1.1

This standard contains requirements for the prevention of loss of life and property damage from fires in motor freight terminals.

1-1.2

This standard applies to freight transfer areas, offices, employee facilities, and to vehicle maintenance and service areas.

1-1.3

This standard applies to motor freight terminals handling freight of various types, including ordinary combustible materials and materials classified as hazardous by the U.S. Department of Transportation Regulations 49 CFR, Parts 100-199.

1-1.3.1 Terminals for truck transportation of explosives shall be in accordance with NFPA 495, *Explosive Materials Code*, and NFPA 498, *Standard for Explosives Motor Vehicle Terminals*.

1-1.3.2 Terminals for bulk shipments of flammable and combustible liquids shall comply with NFPA 30, *Flammable and Combustible Liquids Code*.

1-1.3.3 Terminals for bulk shipments of LP-Gas shall comply with NFPA 58, *Standard for the Storage and Handling of Liquefied Petroleum Gases*.

1-1.4

For general storage buildings, see NFPA 231, *Standard for General Storage*.

1-1.5

For fire protection for property-carrying motor vehicles, see NFPA 512, *Standard for Truck Fire Protection*.

1-1.6

Where existing buildings, structures, and installations meet the applicable requirements of the edition of this standard in effect at the time of construction or installation, they shall be permitted to be continued in use, provided they do not constitute a distinct hazard to life or adjoining property.

1-2 Definitions.

Approved. Acceptable to the authority having jurisdiction.

NOTE: The National Fire Protection Association does not approve, inspect, or certify any installations, procedures, equipment, or materials; nor does it approve or evaluate testing laboratories. In determining the acceptability of installations, procedures, equipment, or materials, the authority having jurisdiction may base acceptance on compliance with NFPA or other appropriate standards. In the absence of such standards, said authority may require evidence of proper installation, procedure, or use. The authority having jurisdiction may also refer to the listings or labeling practices of an organization concerned with product evaluations that is in a position to determine compliance with appropriate standards for the current production of listed items.

Authority Having Jurisdiction. The organization, office, or individual responsible for approving equipment, an installation, or a procedure.

NOTE: The phrase “authority having jurisdiction” is used in NFPA documents in a broad manner, since jurisdictions and approval agencies vary, as do their responsibilities. Where public safety is primary, the authority having jurisdiction may be a federal, state, local, or other regional department or individual such as a fire chief; fire marshal; chief of a fire prevention bureau, labor department, or health department; building official; electrical inspector; or others having statutory authority. For insurance purposes, an insurance inspection department, rating bureau, or other insurance company representative may be the authority having jurisdiction. In many circumstances, the property owner or his or her designated agent assumes the role of the authority having jurisdiction; at government installations, the commanding officer or departmental official may be the authority having jurisdiction.

Class I Liquid. A liquid having a flash point below 100°F (37.8°C).

Fire Area. A portion of a building that is separated from other portions by construction with sufficient fire resistance to prevent fire of maximum anticipated severity from entering or leaving the area and with standard protection at all openings in the surrounding walls, floor, and ceiling. (*See NFPA 80, Standard for Fire Doors and Fire Windows*.)

Freight Transfer Area (Freight Platform, Freight Dock). The area wherein freight is received, sorted, shipped, and held for distribution.

Hazardous Material. A substance or material that has been determined by the Secretary of Transportation to be capable of posing an unreasonable risk to health, safety, and property when transported in commerce and that has been so designated in U.S. Department of Transportation Regulations 49 CFR, Parts 100-199.

Motor Freight Terminal. The area wherein the overall operation of freight transfer, vehicle repair and service, truck parking, and administrative functions are performed. The motor freight terminal might also include facilities for repair of crates, cases, barrels, cartons, or damaged goods; a storage area for undelivered freight or damaged goods pending settlement of claims;

rest rooms; a dormitory for drivers; locker rooms; and meal facilities.

Office Area. That part of the motor freight terminal used for administrative and general offices.

Parking Area. The lot or areas of the motor freight terminals used to park motor vehicles.

Vehicle Maintenance Area. The area wherein vehicles are repaired.

Vehicle Service Area. The area wherein vehicles are serviced, including refueling facilities. The area may include a lane in which vehicles are inspected before being dispatched.

Chapter 2 Construction and Building Arrangement

2-1* Freight Transfer and Administration Buildings.

2-1.1

If not in separate buildings, freight transfer and office areas shall be cut off from vehicle maintenance and service facilities by walls constructed of noncombustible materials having a fire resistance rating of not less than 2 hours. The requirement shall not apply to small offices, 600 ft^2 (54 m^2) or less, located within the vehicle maintenance area.

2-1.2

Walls required by 2-1.1 shall be parapeted at least 3 ft (0.9 m) above the building roof.

Exception: The parapet shall be permitted to be omitted where the wall fits tightly to the underside of a fire-resistive roof deck constructed of noncombustible materials.

2-1.3

Necessary door and other openings in the walls required by 2-1.1 shall be protected by fire doors having a fire protection rating of not less than $1^1/_2$ hours, installed in accordance with NFPA 80, *Standard for Fire Doors and Fire Windows*.

2-1.4

Stairways and other vertical shafts shall be enclosed with construction specified in NFPA 220, *Standard on Types of Building Construction*, or sealed off at each floor level with construction having the same fire resistance rating as the floor.

2-1.5*

Exits and other life safety features of freight transfer and administration buildings and sections of buildings shall comply with the requirements of Chapters 29 and 27, respectively, of NFPA *101®, Life Safety Code®*.

2-1.6

Power-operated doors that are installed in the terminals shall be arranged so that they can be operated manually from the floor in case of power failure.

2-1.7

The floor of any freight transfer area shall be constructed of noncombustible materials without cracks or openings into which trash or other combustible material might fall. This provision shall not prohibit openings for integral freight handling equipment and appurtenances such as slots for the operation of draglines and platform scales. Any open space beneath the floor shall be enclosed with noncombustible material.

2-1.8

Rooms for the storage, charging, and servicing of batteries shall comply with Article 480, NFPA 70, *National Electrical Code*®. "No Smoking" signs shall be posted at the entrance.

2-2* Vehicle Maintenance and Service Buildings.

2-2.1

Service areas that are not located in separate buildings shall be separated from other terminal operations by walls and fire doors in accordance with 2-1.1 through 2-1.3.

2-2.2

Maintenance and service area floors shall be constructed of noncombustible material. Floors shall be graded and equipped with drains so as to minimize the possibility that water or fuel will stand on the floor.

2-2.3

Floor drains shall be provided in areas where vehicles are maintained and serviced. Each floor drain shall be properly trapped and shall discharge through an oil separator to the sewer or outside vented sump.

2-2.4

Pits and subfloor work areas shall be constructed of masonry or concrete, and floors and piers shall be of suitable noncombustible material.

2-2.4.1 Pits shall have adequate exits to prevent trapping of personnel in the event of fire. Steps shall be noncombustible, slip-proof, and constructed with no accessible space underneath.

2-2.4.2 Ventilation and drainage of pits shall be in accordance with Section 5-3.

2-2.5*

Exits from vehicle maintenance and service areas shall comply with the requirements of Section 29-2 of NFPA *101*, *Life Safety Code*.

2-3 Employee Facilities.

2-3.1 Walls and Partitions.

2-3.1.1 Fire resistance ratings of walls or partitions separating the following rooms from surrounding areas shall be as follows:

Employee locker rooms	1 hour
Recreation rooms	1 hour
Sleeping facilities	2 hours

2-3.1.2 Door and other openings in the walls or partitions required by 2-3.1 shall be protected by self-closing fire doors having a fire protection rating of not less than 1 hour, installed in accordance with NFPA 80, *Standard for Fire Doors and Fire Windows*.

Exception: Door and other openings in walls or partitions separating sleeping facilities from surrounding areas shall be protected by self-closing fire doors having a fire protection rating of *not less than $1^1/_2$ hours.*

2-3.2 Floors.

2-3.2.1 Fire resistance ratings of floors separating employee locker rooms, recreation rooms, and sleeping facilities from surrounding areas shall be the same as required for walls or partitions in 2-3.1.

2-3.2.2 Openings in floors between the separated areas shall be enclosed in shafts with enclosing walls or partitions having the same fire resistance ratings as required for the walls or partitions in 2-3.1.

Exception: Ducts for heating, ventilating, and air conditioning shall be installed in accordance with NFPA 90A, Standard for the Installation of Air Conditioning and Ventilating Systems.

2-3.3

Exits and other life safety features of dormitory buildings and dormitory sections of buildings shall comply with the requirements of Chapter 17 of NFPA *101*, *Life Safety Code*.

Chapter 3 Building Services

3-1 Electricity.

3-1.1

All electrical installations shall be in accordance with the provisions of NFPA 70, *National Electrical Code*.

3-1.2

Table 3-1.2 (Table 5-3.5.3 from NFPA 30, *Flammable and Combustible Liquids Code*) shall be used for determining the extent of the hazardous area where flammable liquids are stored or handled.

Table 3-1.2 Electrical Area Classifications

Location	NEC Class I Division	Extent of Classified Area
Indoor equipment installed where flammable vapor-air mixtures may exist under normal operation	1	Area within 5 ft of any edge of such equipment, extending in all directions.
	2	Area between 5 ft and 8 ft of any edge of such equipment, extending in all directions. Also, area up 3 ft above floor or grade level within 5 ft to 25 ft horizontally from any edge of such equipment.*
Outdoor equipment of the type where flammable vapor-air mixtures may exist under normal operation	1	Area within 3 ft of any edge of such equipment, extending in all directions.
	2	Area between 3 ft and 8 ft of any edge of such equipment, extending in all directions. Also, area up 3 ft above floor or grade level within 3 ft to 10 ft horizontally from any edge of such equipment.

Tank—aboveground	1	Area inside dike where dike height is greater than the distance from the tank to the dike for more than 50 percent of the tank circumference.
Shell, ends, or roof and dike area	2	Within 10 ft from shell, ends, or roof of tank. Area inside dikes to level of top of dike.
Vent	1	Within 5 ft of open end of vent, extending in all directions.
	2	Area between 5 ft and 10 ft from open end of vent, extending in all directions.
Floating roof	1	Area above the roof and within the shell.
Underground tank fill opening	1	Any pit, box, or space below grade level, if any part i within a Division 1 or 2 classified area.
	2	Up to 18 in. above grade level, within a horizontal radius of 10 ft from a loose fill connection and withi a horizontal radius of 5 ft from a tight fill connection
Vent—discharging upward	1	Within 3 ft of open end of vent, extending in all directions.
	2	Area between 3 ft and 5 ft of open end of vent, extending in all directions.
Drum and container filling outdoors, or indoors with adequate ventilation	1	Within 3 ft of vent and fill openings, extending in all directions.
	2	Area between 3 ft and 5 ft from vent or fill opening, extending in all directions. Also, up to 18 in. above floor or grade level within a horizontal radius of 10 f from vent or fill openings.
Pumps, bleeders, withdrawal fittings, meters, and similar devices		
Indoors	2	Within 5 ft of any edge of such devices, extending in all directions. Also up to 3 ft above floor or grade level within 25 ft horizontally from any edge of such devices.
Outdoors	2	Within 3 ft of any edge of such devices, extending in all directions. Also up to 18 in. above grade level within 10 ft horizontally from any edge of such devices.
Pits		
Without mechanical ventilation	1	Entire area within pit if any part is within a Division or 2 classified area.
With adequate mechanical ventilation	2	Entire area within pit if any part is within a Division or 2 classified area.
Containing valves, fittings, or piping, and not within a Division 1 or 2 classified area	2	Entire pit.
Drainage ditches, separators, impouding		

basins		
Outdoors	2	Area up to 18 in. above ditch, separator, or basin. Als up to 18 in. above grade within 15 ft horizontally fro any edge.
Indoors		Same as pits.
Tank vehicle and tank car* loading through open dome	1	Within 3 ft of edge of dome, extending in all directions.
	2	Area between 3 ft and 15 ft from edge of dome, extending in all directions.
Loading through bottom connections with atmospheric venting	1	Within 3 ft of point of venting to atmosphere, extending in all directions.
	2	Area between 3 ft and 15 ft from point of venting to atmosphere, extending in all directions. Also up to 18 in. above grade within a horizontal radius of 10 ft from point of loading connection.
Office and rest rooms	Ordinary	If there is any opening to these rooms within the extent of an indoor classified area, the room shall be classified the same as if the wall, curb, or partition di not exist.
Loading through closed dome with atmospheric venting	1	Within 3 ft of open end of vent, extending in all directions.
	2	Area between 3 ft and 15 ft of open end of vent, extending in all directions. Also within 3 ft of edge o dome, extending in all directions.
Loading through closed dome with vapor control	2	Within 3 ft of point of connection of both fill and vapor lines, extending in all directions.
Bottom loading with vapor control Any bottom unloading	2	Within 3 ft of point of connections, extending in all directions. Also up to 18 in. above grade within a horizontal radius of 10 ft from point of connections.
Storage and repair garage for tank	1	All pits or spaces below floor level.
vehicles	2	Area up to 18 in. above floor or grade level for entire storage or repair garage.
Garages for other than tank vehicles	Ordinary	If there is any opening to these rooms within the extent of an outdoor classified area, the entire room shall be classified the same as the area classification a the point of the opening.
Outdoor drum storage	Ordinary	
Indoor warehousing where there is no flammable liquid transfer	Ordinary	If there is any opening to these rooms within the extent of an indoor classified area, the room shall be classified the same as if the wall, curb, or partition di not exist.
Piers and wharves		See Figure 5-3.5.6 in NFPA 30, *Flammable and Combustible Liquids Code*.

*The release of Class I liquids may generate vapors to the extent that the entire building, and possibly a zone surrounding it, should be considered a Class I, Division 2 location.

*When classifying extent of area, consideration shall be given to the fact that tank cars or tank vehicles may be spotted at varying points. Therefore, the extremities of the loading or unloading positions shall be used.

3-2 Heating.

3-2.1

Heating equipment shall be installed to conform with the following standards of the National Fire Protection Association, as applicable: NFPA 90A, *Standard for Installation of Air Conditioning and Ventilating Systems*; NFPA 31, *Standard for the Installation of Oil-Burning Equipment*; NFPA 54, *National Fuel Gas Code*; NFPA 82, *Standard on Incinerators, Waste and Linen Handling Systems and Equipment*; NFPA 211, *Standard for Chimneys, Fireplaces, Vents, and Solid Fuel-Burning Appliances*.

3-2.2

All heating equipment shall be of an approved type designed for the purpose. The use of makeshift or improvised heaters shall be prohibited.

3-2.3

Fuels used shall be of the type and quality specified by the manufacturer of the heating appliance.

3-2.4

Heating equipment shall be permitted to be installed in a special room separated from an area classified as Class I, Division 1 or 2, by walls having a fire-resistive rating of at least 1 hour and without any openings in the wall into the classified area within 8 ft (2.4 m) of the floor. This room shall not be used for combustible storage, and all air for combustion purposes shall come from outside the building. In classifying the areas, Table 3-1.2 shall be used. The area classifications are defined in Article 500 of NFPA 70, *National Electrical Code*.

3-2.5

Heating equipment using gas or oil fuel shall be permitted to be installed in maintenance service areas in which there is no dispensing or transferring of Class I liquids, provided that the bottom of the combustion chamber is at least 18 in. (457 mm) above the floor and the heating equipment is protected from physical damage.

3-2.6

Gas or oil-heating equipment approved for use in garages shall be permitted to be installed in the maintenance and service areas where Class I liquids are dispensed, provided the equipment is installed at least 8 ft (2.4 m) above the floor.

3-2.7

Electrical heating equipment shall be installed in accordance with the provisions of NFPA 70, *National Electrical Code*.

3-3 Ventilation.

3-3.1 Vehicle Maintenance and Repair Areas.

All vehicle maintenance and repair areas, when in operation, shall be continuously ventilated by a ventilating system having positive means for exhausting indoor air at a rate of not less than $^3/_4$ cu ft (0.0212 m^3) of air per minute for each sq ft (m^2) of floor area. Exhaust duct openings for required ventilation shall be located so as to remove effectively vapor accumulations at floor level from all parts of the repair area. An approved means shall be provided for introducing an equal amount of outdoor air.

3-3.2

Mechanical ventilating systems shall be installed in accordance with NFPA 90A, *Standard for the Installation of Air Conditioning and Ventilating Systems*. When blower and exhaust systems are installed for vapor removal, the system shall be installed in accordance with NFPA 91, *Standard for Exhaust Systems for Air Conveying of Materials*.

Chapter 4 Freight Handling Operation

4-1 Freight Transfer.

4-1.1

Aisles shall be provided to keep all portions of the freight handling areas readily accessible for fire fighting and to minimize the spread of fire.

4-1.2*

Hazardous materials shall be handled in accordance with the U.S. Department of Transportation Regulations 49 CFR, Parts 100-199.

4-1.3*

Combustible contents shall not be piled in contact with columns that are not of fire-resistive construction.

4-1.4

In sprinklered buildings, at least 18-in. (457-mm) clearance between sprinkler deflectors and the top of storage shall be maintained. In nonsprinklered buildings, at least 36-in. (914-mm) clearance shall be maintained between the top of the storage and the underside of the roof or ceiling in order to allow sufficient space for effective use of hose streams.

4-1.5*

Clearance shall be maintained between heat-producing appliances and combustible stock in accordance with NFPA 211, *Standard for Chimneys, Fireplaces, Vents, and Solid Fuel-Burning Appliances*. Adequate clearance shall be maintained between incandescent lamps and combustible stock.

4-1.6

A clearance of 24 in. (610 mm) shall be maintained around the path of travel of fire doors.

Exception: If a barricade is provided, no clearance shall be required.

4-1.7

Commodities shall not be stored within 36 in. (914 mm) of a fire door opening.

4-2 Mechanical Handling Equipment.

4-2.1

Power-operated industrial trucks shall be of a type designated in Chapter 1 of NFPA 505, *Fire Safety Standard for Powered Industrial Trucks Including Type Designations, Areas of Use, Maintenance, and Operation*, in accordance with the hazards of the location in which they are used.

4-2.2

Industrial trucks, powered either by liquid or gaseous fuels, or by electricity, shall be inspected and maintained in accordance with Chapters 4 and 5 of NFPA 505, *Fire Safety Standard for Powered Industrial Trucks Including Type Designations, Areas of Use, Maintenance, and Operation*.

4-3 Motor Vehicles at Docks.

4-3.1*

Parking of vehicles in terminals shall be in compliance with applicable local, state, and federal regulations.

4-3.2

Accessibility to terminals and vehicle parking areas for fire fighting purposes shall be provided at all times. Vehicles shall be parked so that they will not block fire department access.

4-3.3

There shall be an emergency plan in effect for the removal of vehicles from the dock to a safe area to minimize fire exposure and loss and to ensure improved accessibility for the fire fighting equipment.

Chapter 5 Vehicle Maintenance and Service

5-1 General.

Major maintenance and servicing of motor vehicles shall not be performed on floors below grade level. This requirement shall not prohibit the use of pits.

5-2 Spray Painting and Undercoating.

Spray painting, drying, and undercoating of motor vehicles shall conform to NFPA 33, *Standard for Spray Application Using Flammable and Combustible Materials*, and NFPA 86, *Standard for Ovens and Furnaces*.

5-3* Inspection and Repair Pits.

5-3.1

Use of approved portable lights shall be minimized by installation of fixed lighting fixtures of the approved types in all pits in accordance with Article 511 of NFPA 70, *National Electrical Code*.

Exception: If gasoline is dispensed, Article 514 of NFPA 70, National Electrical Code, shall apply.

5-3.2

Drainage from inspection or repair pits shall not enter a storm or sanitary sewer system, unless it has passed through a separator to prevent flammable and combustible liquids from entering the sewer.

5-3.3

Smoking in pits shall be prohibited.

5-3.4

A scheduled maintenance program for the collection and removal of oil separators and traps shall be initiated to prevent flammable and combustible liquids from entering the sewer.

5-4 Repair of Fuel Tanks.

5-4.1

Repair work on fuel tanks of vehicles shall be in accordance with NFPA 327, *Standard Procedures for Cleaning or Safeguarding Small Tanks and Containers Without Entry*, and NFPA 58, *Standard for the Storage and Handling of Liquefied Petroleum Gases*.

5-4.2

Fuel drained from vehicle tanks and not discarded shall be stored in approved safety cans or returned to standard underground storage tanks.

5-5 Cleaning of Parts.

Cleaning of parts shall be performed with nonflammable solvent.

Exception: A combustible liquid with a flash point at or above 100°F (37.8°C) (closed cup) shall be permitted to be used for this purpose, provided adequate ventilation is supplied and no sources of ignition are present in the cleaning area.

5-6 Welding and Open Flame Operations.

5-6.1

All operations involving open flame or electric arcs, including fusion gas and electric welding, shall be restricted to the designated repair area. This provision includes, but is not limited to, fuel tank and radiator repairs. Responsibility for cutting and welding, and related fire prevention precautions, shall be in accordance with the requirements of NFPA 51B, *Standard for Fire Prevention in Use of Cutting and Welding Processes*.

5-6.2

Welding equipment shall conform to Article 630 of NFPA 70, *National Electrical Code*, and the welding operations shall conform to NFPA 51, *Standard for the Design and Installation of Oxygen-Fuel Gas Systems for Welding, Cutting, and Allied Processes*.

5-7 Storage and Handling of Flammable and Combustible Liquids.

The storage and handling of flammable and combustible liquids shall be in accordance with NFPA 30, *Flammable and Combustible Liquids Code*. The storage and handling of liquefied petroleum gas shall be in compliance with NFPA 58, *Standard for the Storage and Handling of Liquefied Petroleum Gases*.

5-8 Fueling of Vehicles.

5-8.1*

Gasoline dispensing units shall be of an approved type and shall be at least 20 ft (6 m) horizontally from any activity involving fixed sources of ignition.

5-8.2

Approved dispensing units shall be permitted to be located inside buildings upon specific approval of the authority having jurisdiction. The dispensing area shall be separated from other areas in a manner approved by the authority having jurisdiction. The dispensing area shall be provided with an approved mechanical or gravity ventilation system.

5-8.3

Class I liquids shall be transferred from tanks by means of fixed pumps designed and equipped to allow control of the flow and prevent leakage or accidental discharge.

5-8.4

The dispensing unit and its piping, except those units attached to containers, shall be mounted on a concrete island or protected against collision damage by suitable means. If located indoors, the dispenser also shall be mounted on a concrete island or shall be protected against collision damage by suitable means and shall be located in a position where it cannot be struck by an out-of-control vehicle that is descending a ramp or other slope.

5-8.5

If Class I liquids are dispensed by a person other than the attendant, the hose nozzle valve shall be a listed automatic-closing type without a hold-open latch.

5-8.6

One or more clearly identified and easily accessible switches or circuit breakers shall be provided at a location remote from dispensing devices, including remote pumping systems, to shut off the power to all dispensing devices in the event of an emergency. Controls shall not be more than 100 ft (30 m) from dispensers.

5-8.7

Operating instructions and “No Smoking” signs shall be conspicuously posted in the dispensing area.

5-8.8

The storage and handling of flammable and combustible liquids shall be in accordance with NFPA 30, *Flammable and Combustible Liquids Code*.

5-8.9

Facilities for filling LP-Gas fuel tanks shall be located outside of any terminal building. For requirements for LP-Gas fueling, see NFPA 58, *Standard for the Storage and Handling of Liquefied Petroleum Gases*.

Chapter 6 Fire Protection

6-1* Automatic Sprinklers.

Where automatic sprinklers are provided, they shall be installed in accordance with NFPA 13, *Standard for the Installation of Sprinkler Systems*.

6-2 Portable Fire Extinguishers.

Portable fire extinguishers shall be installed, inspected, maintained, and used in accordance with NFPA 10, *Standard for Portable Fire Extinguishers*.

6-3 Standpipes.

Where standpipe and hose systems are provided, they shall conform to NFPA 14, *Standard for the Installation of Standpipe and Hose Systems*.

6-4* Alarm Service.

Where alarm service is provided, it shall be installed and maintained in accordance with NFPA 72, *National Fire Alarm Code*.

6-5 Outside Protection.

6-5.1*

The fire fighting needs of the terminal buildings and the requirements for fighting fires that might involve loaded and unloaded vehicles shall be considered when determining water supply and hydrant requirements.

6-5.2

Where private underground supply mains and hydrants are necessary, they shall be installed in accordance with NFPA 24, *Standard for the Installation of Private Fire Service Mains and Their Appurtenances*.

Chapter 7 Referenced Publications

7-1

The following documents or portions thereof are referenced within this standard and shall be considered part of the requirements of this document. The edition indicated for each reference is the current edition as of the date of the NFPA issuance of this document.

7-1.1 NFPA Publications.

National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.

NFPA 10, *Standard for Portable Fire Extinguishers*, 1990 edition.

NFPA 13, *Standard for the Installation of Sprinkler Systems*, 1994 edition.

NFPA 14, *Standard for the Installation of Standpipe and Hose Systems*, 1993 edition.

NFPA 24, *Standard for the Installation of Private Fire Service Mains and Their Appurtenances*, 1992 edition.

NFPA 30, *Flammable and Combustible Liquids Code*, 1993 edition.

NFPA 31, *Standard for the Installation of Oil-Burning Equipment*, 1992 edition.

NFPA 33, *Standard for Spray Application Using Flammable and Combustible Materials*, 1989 edition.

NFPA 51, *Standard for the Design and Installation of Oxygen-Fuel Gas Systems for Welding, Cutting, and Allied Processes*, 1992 edition.

NFPA 51B, *Standard for Fire Prevention in Use of Cutting and Welding Processes*, 1994 edition.

NFPA 54, *National Fuel Gas Code*, 1992 edition.

NFPA 58, *Standard for the Storage and Handling of Liquefied Petroleum Gases*, 1992 edition.

NFPA 70, *National Electrical Code*, 1993 edition.

NFPA 72, *National Fire Alarm Code*, 1993 edition.

NFPA 80, *Standard for Fire Doors and Fire Windows*, 1992 edition.

NFPA 82, *Standard on Incinerators, Waste and Linen Handling Systems and Equipment*, 1994 edition.

NFPA 86, *Standard for Ovens and Furnaces*, 1990 edition.

NFPA 90A, *Standard for the Installation of Air Conditioning and Ventilating Systems*, 1993 edition.

NFPA 91, *Standard for Exhaust Systems for Air Conveying of Materials*, 1992 edition.

NFPA *101*, *Life Safety Code*, 1994 edition.

NFPA 211, *Standard for Chimneys, Fireplaces, Vents, and Solid Fuel-Burning Appliances*, 1992 edition.

NFPA 220, *Standard on Types of Building Construction*, 1992 edition.

NFPA 327, *Standard Procedures for Cleaning or Safeguarding Small Tanks and Containers Without Entry*, 1993 edition.

NFPA 495, *Explosive Materials Code*, 1992 edition.

NFPA 498, *Standard for Explosives Motor Vehicle Terminals*, 1992 edition.

NFPA 505, *Fire Safety Standard for Powered Industrial Trucks Including Type Designations, Areas of Use, Maintenance, and Operation*, 1992 edition.

7-1.2 Other Publication.

7-1.2.1 U.S. Department of Transportation Regulations, 400 7th Street, SW, Washington, DC 20590.

49 CFR, Parts 100-199, as amended.

Appendix A Explanatory Material

This Appendix is not a part of the requirements of this NFPA document, but is included for informational purposes only.

A-2-1

Freight transfer and administration buildings should be of fire-resistive or noncombustible construction as defined in NFPA 220, *Standard on Types of Building Construction*. Consideration should be given to limitation of undivided fire areas in freight transfer facilities.

Factors to be considered when determining maximum sizes of undivided fire areas are (a) type of fire protection provided, (b) mechanical conveying equipment such as dragline operations, and (c) surveillance of goods to prevent possible theft.

A-2-1.5

The referenced sections of NFPA *101*, *Life Safety Code*, include requirements for types and capacity of exits, travel distances to exits, access to exits, exit lighting and signs, protection of vertical openings, interior finish, alarms, and air-conditioning equipment.

A-2-2

Areas used for repairing and servicing vehicles should be located in separate buildings from the freight transfer building. These buildings should be of fire-resistive or noncombustible construction.

A-2-2.5

Chapter 29 of NFPA *101*, *Life Safety Code*, includes requirements for types and capacity of exits, travel distances to exits, access to exits, exit lighting and signs, protection of vertical openings, interior finish, and alarms.

A-4-1.2

Certain commodities have characteristics that cause them to be classified as hazardous materials. These commodities are subject to special regulations governing packaging, storage, and transportation. Failure to abide by these requirements increases the danger of explosion, fire, the release of noxious or toxic fumes, damage to other freight, or other dangerous conditions. Section 177.848 of the *Code of Federal Regulations*, *Loading and Storage Guide*, sets forth those combinations of hazardous materials that should not be loaded or stored together, or with certain other types of freight, in the same vehicle. The *Loading and Storage Guide* does not prohibit the presence of these combinations of commodities in the same motor freight terminal so long as they are not stored adjacent to each other.

A-4-1.3

This requirement is necessary to permit water to wet columns during fire suppression operations to guard against column failure.

A-4-1.5

Surface temperature of lamps is discussed in the NFPA *Fire Protection Handbook*, 17th edition, pages 2-34.

A-4-3.1

In case of fire, there is a potential for mutual exposure between the terminals and vehicles parked adjacent to them. Consistent with operating conditions and security requirements, consideration should be given to minimizing the potential exposure by not parking vehicles at the dock longer than necessary. Priority should be given to the loading, unloading, and dispatching of vehicles transporting hazardous materials so that such cargoes will not be in the terminal longer than necessary.

A-5-3

Pits used to service gasoline-fueled vehicles should be provided with individual ventilating systems capable of providing 4 cu ft (0.1132 m^3) of air per minute per sq ft (m^2) of floor area. Such pits should have the floor pitched 1 in. (25.4 mm) for each 10 ft (3.05 m), and the exhaust air opening should terminate in an air opening that is perpendicular to the floor with the bottom of the opening extending to the floor at the lowest end of the pit.

A-5-8.1

In fuel dispensing, consideration should be given to the vapor recovery requirements of the U.S. Environmental Protection Agency.

A-6.1

Consideration should be given to sprinkler protection for:

(a) Freight transfer buildings and vehicle maintenance and service buildings.

(b) Truck loading areas. An open head deluge system or a closed head dry pipe or nonfreeze-solution wet system should be provided in colder regions to protect against the mutual fire exposure that can exist between terminals and vehicles parked adjacent to them. See Chapter 3, “System Requirements,” of NFPA 13, *Standard for the Installation of Sprinkler Systems*.

A-6-4

Freight transfer facilities should be provided with one of the following types of alarm service: (a) central station supervision of sprinkler system water-flow, (b) central station supervision of automatic fire detection system, or (c) central station supervision of guard service. Details for the installation, maintenance, and use of guard, fire alarm, and sprinkler supervisory systems are found in NFPA 72, *National Fire Alarm Code*. Information on the selection and training of persons to perform guard services is found in NFPA 601, *Standard on Guard Service in Fire Loss Prevention*.

A-6-5.1

Where an adequate water supply for fire hydrants and sprinkler protection cannot be made available from public water mains, the following NFPA standards should be consulted: NFPA 20, *Standard for the Installation of Centrifugal Fire Pumps*, and NFPA 22, *Standard for Water Tanks for Private Fire Protection*.

Appendix B Referenced Publications

B-1

The following documents or portions thereof are referenced within this standard for informational purposes only and thus are not considered part of the requirements of this document. The edition indicated for each reference is the current edition as of the date of the NFPA issuance of this document.

B-1.1 NFPA Publications.

National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA

02269-9101.

NFPA 13, *Standard for the Installation of Sprinkler Systems*, 1994 edition.

NFPA 20, *Standard for the Installation of Centrifugal Fire Pumps*, 1993 edition.

NFPA 22, *Standard for Water Tanks for Private Fire Protection*, 1993 edition.

NFPA 72, *National Fire Alarm Code*, 1993 edition.

NFPA 80, *Standard for Fire Doors and Fire Windows*, 1992 edition.

NFPA *101*, *Life Safety Code*, 1994 edition.

NFPA 220, *Standard on Types of Building Construction*, 1992 edition.

NFPA 231, *Standard for General Storage*, 1990 edition.

NFPA 512, *Standard for Truck Fire Protection*, 1994 edition.

NFPA 601, *Standard on Guard Service in Fire Loss Prevention*, 1992 edition.

Fire Protection Handbook, 1993, 17th edition.

B-1.2 Other Publications.

B-1.2.1 U.S. Department of Transportation Publication. U.S. Department of Transportation, 400 7th Street, SW, Washington, DC 20590.

Code of Federal Regulations, 49 CFR, Parts 100-199.

B-1.2.2 U.S. Environmental Protection Agency Publication. U.S. Environmental Protection Agency, Waterside Mall, 401 M Street, SW, Washington, DC 20460.

Code of Federal Regulations, 40 CFR, Section 50.

NFPA 550

1995 Edition

Guide to the Fire Safety Concepts Tree

1995 Edition

This edition of NFPA 550, *Guide to the Fire Safety Concepts Tree*, was prepared by the Standards Council and acted on by the National Fire Protection Association, Inc., at its Fall Meeting held November 14-16, 1994, in Toronto, Ontario, Canada. It was issued by the Standards Council on January 13, 1995, with an effective date of February 7, 1995, and supersedes all previous editions.

The 1995 edition of this document has been approved by the American National Standards Institute.

Origin and Development of NFPA 550

The NFPA Committee on Systems Concepts was organized to be responsible for developing systems concepts and criteria for fire protection in structures. A primary accomplishment of this committee was the development of the NFPA Fire Safety Concepts Tree. This guide to the Fire Safety Concepts Tree was developed by the Committee on Systems Concepts in 1985. Appreciation is extended to Dr. John M. Watts, Jr., of the Fire Safety Institute for his major contribution to the contents of this document.

The Committee on Systems Concepts was discharged in October 1990, and the Standards Council assumed the responsibility for this document.

The 1995 edition represents a reconfirmation of the 1986 edition with editorial clarifications.

Report of the Standards Council

NFPA 550
Guide to the
Fire Safety Concepts Tree

1995 Edition

NOTICE: Information on referenced publications can be found in Chapter 8 and Appendix A.

Chapter 1 Introduction

1-1 General.

The critical need for reliability in the U.S. space program generated a new discipline known as System Safety Analysis. Many analytical approaches to safety have evolved in this new field. One of the more powerful tools is Fault Tree Analysis. Fault Tree Analysis uses a tree-like diagram to describe the relationships of events that can lead to a system failure (*see Appendix B*). The NFPA Fire Safety Concepts Tree uses a similar diagram to show relationships of fire prevention and fire damage control strategies.

Fire safety features such as construction type, combustibility of contents, protection devices, and characteristics of occupants traditionally have been considered independently of one another. This can lead to unnecessary duplication of protection. On the other hand, gaps in protection can exist when these pieces do not come together adequately, as evidenced by the large losses that continue to occur.

The distinct advantage of the Fire Safety Concepts Tree is its systems approach to fire safety. Rather than considering each feature of fire safety separately, the Fire Safety Concepts Tree examines all of them and demonstrates how they influence the achievement of fire safety goals and objectives.

1-2 Scope and Application.

The Fire Safety Concepts Tree is useful in providing an overall structure with which to analyze the potential impact of various codes and standards on a particular fire safety problem. It can identify gaps and areas of redundancy in alternative fire protection strategies as an aid in making fire safety decisions. The use of the Fire Safety Concepts Tree should be accompanied by the application of sound fire protection engineering principles.

1-3 Purpose.

This guide is intended to answer questions that have been asked during the past twenty years and to stimulate new questions. Fire safety is not a static concept but evolves with the expansion of our knowledge of the nature of fire and with the imagination of the fire safety practitioner.

Chapter 2 Background

2-1 General.

In the 1960s, there was growing awareness that modern high-rise buildings designed in accordance with building codes and standards were deficient in fire safety protection. In response, a special workshop and follow-up conference of selected experts was convened to consider systematic ways of developing new or revised approaches to fire safety. These conferences, held in 1971, were brainstorming sessions that had the objective of producing a logical framework for providing adequate fire safety in high-rise structures. They were the stimulus for the organization of a special NFPA committee with the scope of being "responsible for developing systems concepts and criteria for fire protection in structures." A primary accomplishment of the Committee on Systems Concepts was development of the NFPA Fire Safety Concepts Tree.

2-2 Current Application.

The original committee document, published in 1974, was a logic diagram referred to as the "Decision Tree." This term was used to identify the tree as an aid to fire safety decision-making. While the Decision Tree incorporated the logic and structure of a fault tree, it described paths leading to success rather than failure. Another important distinction separating the Decision Tree from a fault tree was that components of fire safety are not always well-defined events to which a probability of occurrence can be assigned. In order to emphasize that the tree components are concepts rather than events, it was renamed the Fire Safety Concepts Tree when it was revised and updated in 1980.

The NFPA Fire Safety Concepts Tree is printed on a single large sheet of paper and folded approximately into letter size. Unfolding and spreading out the tree permits the entire fire safety process to be viewed at once.

Chapter 3 Structure of the Fire Safety Concepts Tree

3-1 Fire Safety Objectives.

At the top of the NFPA Fire Safety Concepts Tree is a box labeled "FIRE SAFETY OBJECTIVE(S)." The logic of the tree is directed toward the achievement of specified objectives, as in the recognized approach of "Management by Objectives" (MBO). In this case, the concern is for managing the fire risk. The concept is that the clearer the idea one has of the objective, the greater the chance of achieving it. The three basic fire safety objectives are life safety, property protection, and operational continuity. More specific operating objectives might include averting a catastrophic loss, avoiding public anxiety, preserving for posterity, and environmental protection.

Strategies for achieving fire safety objectives are divided into two categories: PREVENT FIRE IGNITION and MANAGE FIRE IMPACT. These concepts are connected through an "OR gate" to the fire safety objectives. This is shown on the printed tree by the lines drawn from the top of the boxes labeled PREVENT FIRE IGNITION and MANAGE FIRE IMPACT, which join together and lead upward through a circle with a plus symbol in it to the box labeled FIRE SAFETY OBJECTIVE(S) (*see Figure 3-1*). The circle containing the plus symbol (⊕) is used to designate an OR gate. An OR gate is a logic operation whereby any of several inputs will produce a specified output. Thus, the logic of the tree is that fire safety objectives can be accomplished by preventing a fire from starting *or* by managing the impact of the fire. Note that although there is a tendency to read the tree from the top down, the logic flow is upward, i.e., the inputs are below the outputs.

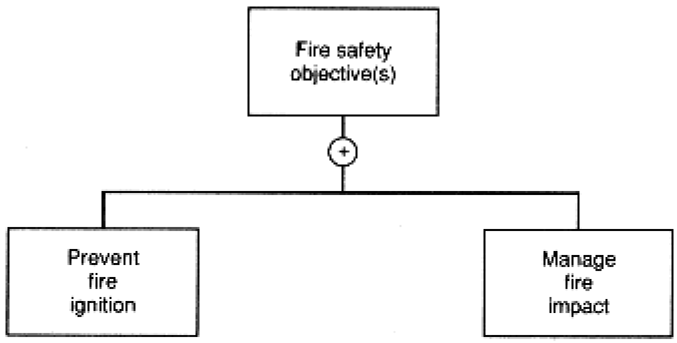


Figure 3-1 Top gate of Fire Safety Concepts Tree.

The OR gate is the "inclusive or," which means that all the concepts below the gate can be included, but only one of them is necessary. In theory, this implies that either prevention or management alone could be followed to achieve the objective. However, theoretically, it is not possible to achieve perfect prevention or management. In practice, principles of both fire prevention and fire impact management usually are applied together. The likelihood of achieving fire safety objectives is increased by the presence of both principles. This practice is an example of reliability through redundancy, e.g., using both a belt and suspenders to hold up a pair of pants. Thus, OR gates in the Fire Safety Concepts Tree indicate where reliability of achieving an objective is improved by implementation of more than one strategy. It is also important to note that the inputs to an OR gate are exhaustive. This means they encompass every possible way of achieving the indicated output.

3-2 Prevent Fire Ignition.

The PREVENT FIRE IGNITION branch of the Fire Safety Concepts Tree includes measures representative of a fire prevention code. Fire safety measures included in this branch of the tree require continuous monitoring to ensure their effectiveness. The responsibility, therefore, is more the owner's or occupant's than the designer's.

Ignition results from a heat source in contact with, or sufficiently close to, a combustible substance. Thus, PREVENT FIRE IGNITION branches into CONTROL HEAT-ENERGY SOURCE(S), CONTROL SOURCE-FUEL INTERACTIONS, *or* CONTROL FUEL [*see Figure 3-2(a)*]. Again, the OR gate indicates that any one of these three strategies, if carried out fully, is sufficient to prevent ignition, but use of more than one will improve the chances of prevention.

For example, control of heat-energy sources can be achieved by eliminating them. This also achieves the prevention of fire ignition, and no other strategy is needed. However, there is a reliability associated with the strategy of eliminating all heat-energy sources, i.e., it is possible that somehow an ignition source might find its way into the protected area. If the control fuel strategy also is applied, then the reliability that ignition will be prevented is increased.

CONTROL SOURCE-FUEL INTERACTIONS is the output of an “AND gate” with input strategies of CONTROL HEAT-ENERGY SOURCE TRANSPORT, CONTROL HEAT-ENERGY TRANSFER PROCESSES, *and* CONTROL FUEL TRANSPORT. On the printed tree, the symbol for an AND gate is a circle with a dot in the middle The AND gate is the logic operation that indicates all of the inputs must coexist simultaneously in order to produce the output. This means that the heat source should not be allowed to move too close to the fuel, excessive heat should be prevented from being transferred to the fuel, *and* the fuel should not be allowed to move too close to the heat source. All these concepts are necessary to achieve control of source-fuel interactions; there is no redundancy. AND gates in the Fire Safety Concepts Tree represent checklists of items that are necessary to achieve the output objective or strategy.

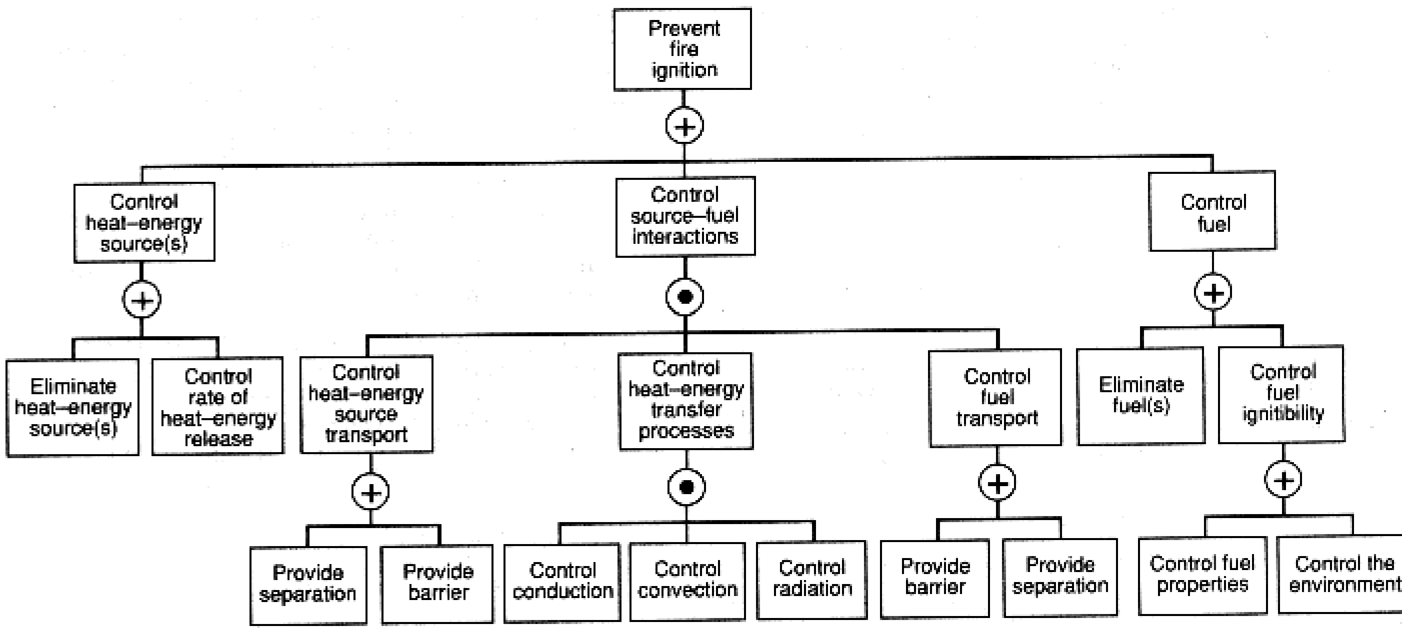


Figure 3-2(a) Prevent fire ignition branch of Fire Safety Concepts Tree.

The plus and dot symbols used for OR gates and AND gates [*see Figure 3-2(b)*] also are used in fault trees. They are the standard symbols for these logic operations, which are used in electronic circuit diagrams and Boolean algebra. They are derived from the algebra of probabilities. (*See Appendix C.*)

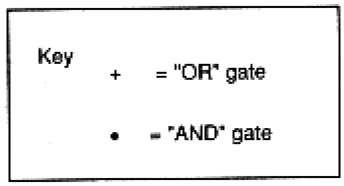


Figure 3-2(b) Logic symbols used in Fire Safety Concepts Tree.

3-3 Manage Fire Impact.

The MANAGE FIRE IMPACT side of the tree has two major branches as inputs to an OR gate: MANAGE FIRE and MANAGE EXPOSED (*see Figure 3-3*). This is the basic approach to loss control, i.e., to limit the magnitude of the hazard or to minimize the effects.

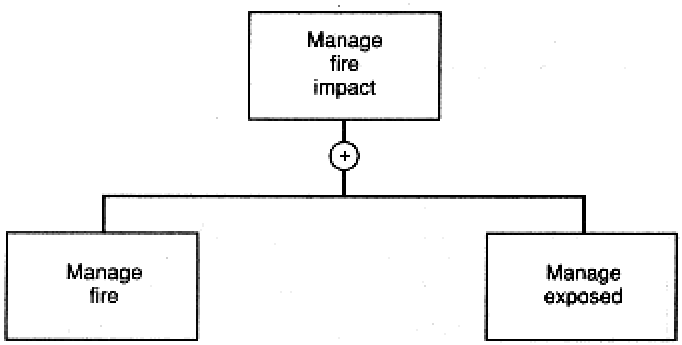


Figure 3-3 Major branches of manage fire impact.

3-3.1 Manage Fire.

The objectives of the MANAGE FIRE strategy are to reduce hazards associated with fire growth and spread, and to thereby reduce the impact of the fire. Approaches to fire management are (1) control the rate of production of smoke and heat through alteration of the fuel or the environment, (2) control the combustion process by manual or automatic suppression, and (3) control fire propagation with venting or containment, or both (*see Figure 3-3.1*). Again, the OR gate indicates that these strategies can be applied simultaneously for increased reliability of managing the fire.

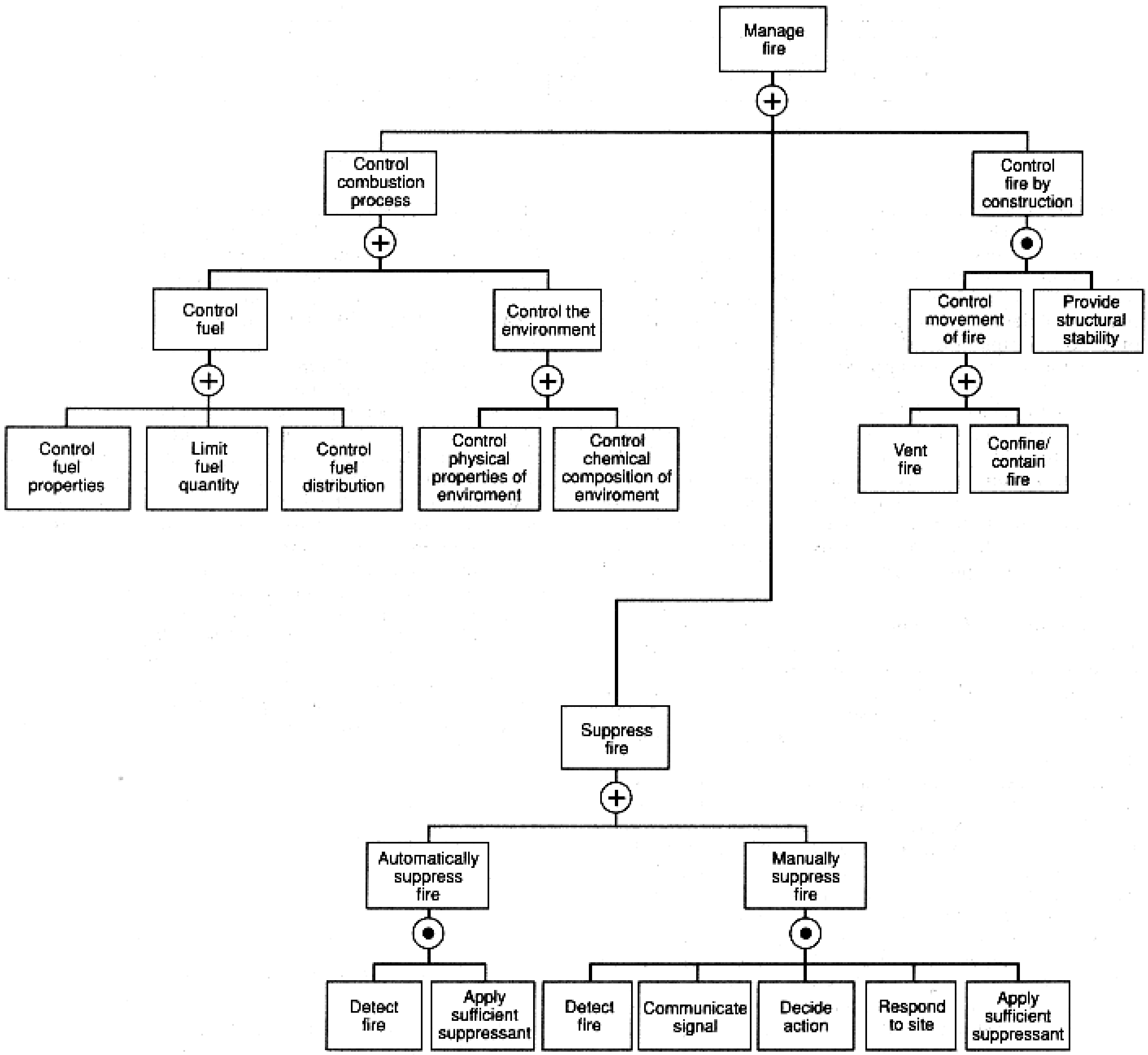


Figure 3-3.1 Manage fire branch of Fire Safety Concepts Tree.

3-3.2 Manage Exposed.

MANAGE EXPOSED means to coordinate measures involving any or all of the items specified in the fire safety objectives, e.g., people, property, activities, or other valuable considerations. The MANAGE EXPOSED branch is achieved by either limiting the number of individuals and amount of property that are exposed or safeguarding all persons and property subject to exposure [*see Figure 3-3.2(a)*]. In the case of property or immobile persons, such as nonambulatory hospital patients, the exposed is safeguarded most often by defending the occupied space from fire exposure. “Hardening against fire” is another term for the strategy of making the exposed resistant to the effects of fire. For more mobile occupants, the most common strategy for safeguarding the exposed is to relocate the exposed while protecting the route for the duration of transit.

The transfer symbol labeled “entry point” in the key to the Fire Safety Concepts Tree is shown in Figure 3-3.2(b).

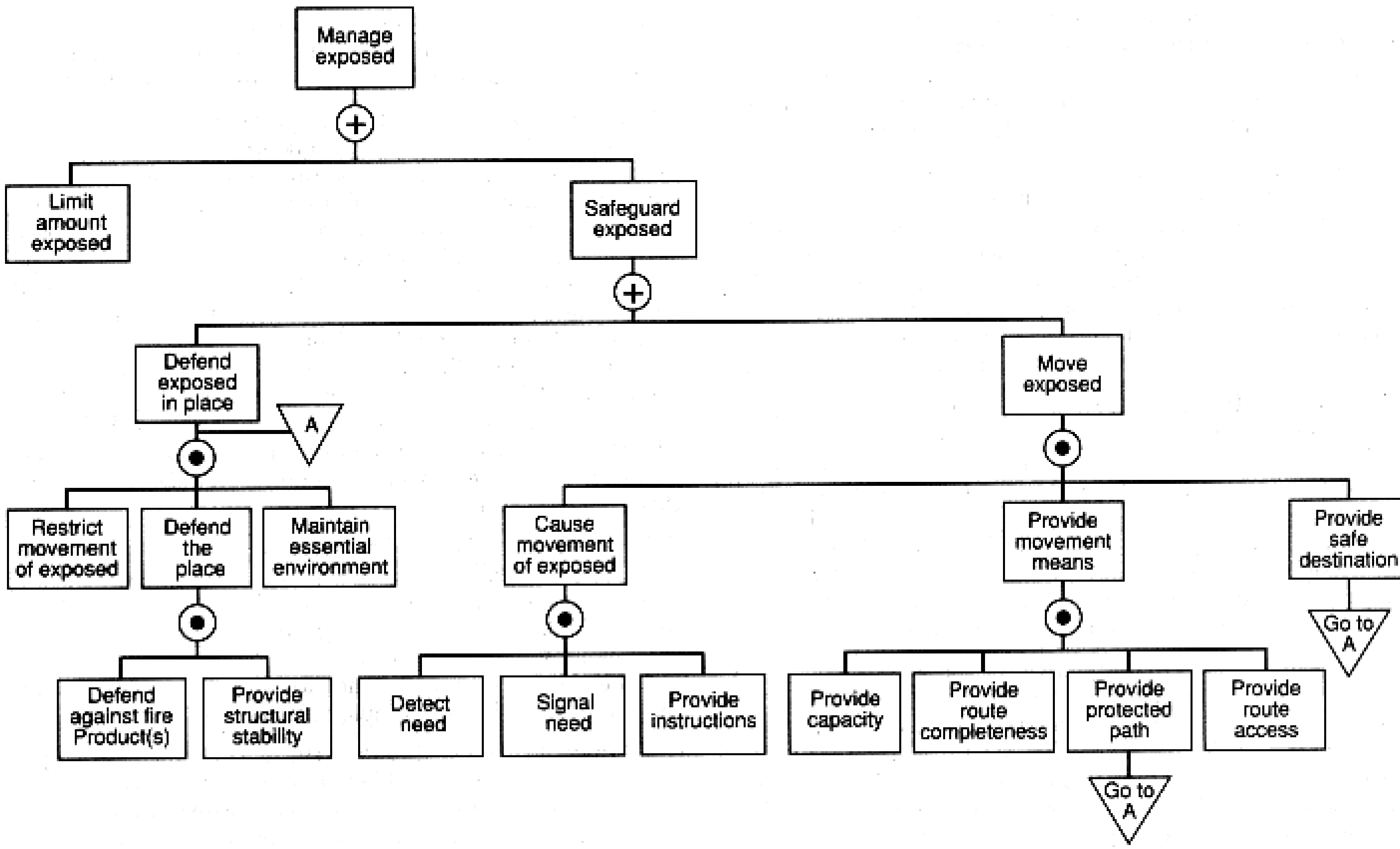


Figure 3-3.2(a) Manage exposed branch of Fire Safety Concepts Tree.

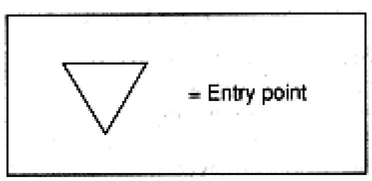


Figure 3-3.2(b) Transfer symbol.

This transfer symbol indicates where portions of the tree are repeated. In Figure 3-3.2(a), the portion of the tree under the element DEFEND EXPOSED IN PLACE is repeated under the elements PROVIDE SAFE DESTINATION and PROVIDE PROTECTED PATH.

Chapter 4 Applications

4-1 General.

The Fire Safety Concepts Tree is a general qualitative guide to fire safety. It is a flexible tool that can be used in a number of different ways.

4-2 Communications.

Perhaps the most important use of the tree is for communication with architects and other professionals involved in building design and management. Codes and standards are not intended to be tutorial; they presume a significant level of comprehension of the principles of fire protection engineering. The Fire Safety Concepts Tree is a simple visual representation of the total concept of fire safety incorporated in codes and standards. It can be used as a means of communication between fire safety specialists and others to help identify the role of specific requirements. The tree can be considered as a first level of education in fire protection engineering, i.e., as an introduction to the full breadth of the subject.

4-3 Code Equivalency.

A more specific application of the Fire Safety Concepts Tree is its use as an adjunct to building codes. An important feature in building codes is the provision for “equivalencies.” Equivalency clauses state that alternatives to specified code requirements are acceptable if they provide a degree of fire safety equivalent to that of the code. The Fire Safety Concepts Tree provides a guide to the determination of equivalency. OR gates indicate where more than one means of accomplishing a strategy in the tree is possible. A decrease in the quality or quantity of one input to an OR gate can be balanced by an increase in another input to the same gate. However, it should be emphasized that this application is subjective. Comparative values of tradeoffs usually are determined by experienced judgment. The importance of the tree is that it provides guidance in which concepts to assess.

4-4 Building Management.

The Fire Safety Concepts Tree can be used to assess fire safety in an existing building. Inputs to AND gates in the tree comprise a checklist of required components that should be maintained in order to accomplish their respective strategies. Thus, in a structure for which particular strategies are identified as necessary to achieve fire safety objectives, appraisal of inputs to those strategies constitutes a fire safety assessment of the structure.

4-5 Building Design.

Ideally, the Fire Safety Concepts Tree is a design tool. Once basic fire safety objectives for a building are identified, the designer can analyze the alternative tree paths through which these objectives can be met. Examination of the OR gates in the tree indicates where alternative strategies exist and where redundancies can be built into the design to improve reliability. The tree then can be used to communicate the fire safety concepts of the design to management and code officials.

4-6 Research.

Another application of the Fire Safety Concepts Tree is as a research tool. The tree can be used to classify fire safety strategies as a guide for research activities. In one case, an investigation to determine alternatives to federal fire safety requirements for housing projects began with an analysis of residential fire safety using the Fire Safety Concepts Tree. In another research project, qualitative techniques of fault tree analysis were applied to the Fire Safety Concepts Tree to produce an exhaustive set of fire safety strategies to compare the effectiveness of specific fire safety variables. A similar approach was used to link fire safety objectives with specific features in a study of hospital fire safety in the United Kingdom.

4-7 Other Applications.

The applications described above represent only some of the more common uses of the Fire Safety Concepts Tree. In addition, the tree has been used or proposed for use as a guide to code organization, standards organization, information retrieval, curriculum development, marketing, indexing, and fire investigation. A major U.S. corporation adapted the Fire Safety Concepts Tree as a table of contents to their “Fire Safety Practices,” and the U.S. Department of State developed an approach based on the Fire Safety Concepts Tree to evaluate their foreign property. Among the more than 10,000 trees that have been “planted” (i.e., distributed) by NFPA, there are hundreds of different applications likely, limited in scope only by the imagination of the user.

Chapter 5 Limitations

5-1 General.

The NFPA Fire Safety Concepts Tree has met with some success as a comprehensive qualitative guide to fire safety. It allows identification of alternatives and combinations of fire safety as well as the identification of redundancies and gaps. However, there are significant limitations to its application.

5-2 Interaction of Concepts.

The tree structure does not adequately consider multiple interactions of fire safety concepts, i.e., concepts that are inputs to more than one strategy. This is most apparent in regard to the combined contribution of detection systems to the management of fire and to the management of the exposed. The logic tree approach does not portray lateral influences of fire safety components, i.e., concepts at the same level in the tree that affect each other.

5-3 Time Factors.

One of the major limitations of fire safety trees is the lack of chronological sequences. Fire safety depends on the elimination of combustion products and people coexisting in the same place at the same time. That is, avoidance of fire casualties depends on the avoidance of exposure in both space and time. One can either endure a fire or escape it. To escape a fire means to move faster than the fire and its products of combustion. The temporal aspect of fire development is not represented in the Fire Safety Concepts Tree.

The Fire Safety Concepts Tree does not indicate where inputs to AND gates need to be sequential. For example, the basic elements that are inputs to MANUALLY SUPPRESS FIRE have an implied order in which they should occur. No distinction is made to identify AND gates where this implicit order exists.

5-4 Objectives.

The NFPA Fire Safety Concepts Tree is limited in its ability to deal simultaneously with multiple objectives. There can be ten or more distinct fire safety objectives for buildings, each requiring a different course of action. Although a series of trees can be used to evaluate the success of achieving each objective individually, there is no convenient way to deal with multiple objectives collectively.

5-5 Quantification.

Ideally, the Fire Safety Concepts Tree could be quantified like a fault tree. However, assigning probabilities or other numerical measures to fire safety tree “concepts” is much more difficult than identifying probabilities for fault tree “events.” It is unlikely that the NFPA tree in its present form will be satisfactorily quantified in the near future.

Chapter 6 Use of the Tree

6-1 General.

There are many methods for using the Fire Safety Concepts Tree. These range from cursory visual examination, through systematic consideration of each concept, to adaption for quantitative analysis. This section illustrates one systematic approach to qualitative assessment of fire safety. The references in Appendix A describe other approaches to using the tree.

6-2 A Procedure.

The following procedure is a step-by-step approach for one way in which the Fire Safety Concepts Tree can be used to evaluate fire safety. It should not be inferred that this is the only way the tree can be used. As indicated previously, there is a wide variety of applications and methods for using the Fire Safety Concepts Tree.

6-2.1 Step One.

Define the objectives. This is the most important step in making any decision. It is difficult to find the best solution to the wrong problem. This question should be asked: “What do I want the fire safety system to do?” (e.g., provide a high level of assurance that operations will not be interrupted; meet the intention of the code; minimize the possibility of a multiple fatality fire; etc.).

6-2.2 Step Two.

Assess each of the lowest elements in the tree, i.e., all elements that do not have any inputs. For the particular structure in question, estimate the extent to which each basic element is present as a fire safety feature. For example, consider a simple scale made up of four categories: nonexistent, below standard, standard, and above standard, where “standard” indicates an appropriate level of consensus. Next, label each of the lowest elements according to its applicable category. Evaluation should include consideration of the reliability of fire safety systems to perform as designed.

6-2.3 Step Three.

Where the lowest level elements are inputs to an OR gate, the value of the output will be at least as high as the highest valued input. For example, if compliance with the strategy

ELIMINATE HEAT-ENERGY SOURCE(S) is only partial, it might be evaluated as "below standard." Similarly, if the only heat-energy source is electricity and the installation is in accordance with NFPA 70, *National Electrical Code*®, CONTROL RATE OF HEAT-ENERGY RELEASE could qualify as "standard." Therefore, CONTROL HEAT-ENERGY SOURCE(S) as the output of an OR gate would be rated as at least "standard."

6-2.4 Step Four.

Where the lowest level elements are inputs to an AND gate, the quality of the output is limited to that of the least valued input. For example, consider an automatic sprinkler system with appropriately temperature-rated sprinklers spaced according to NFPA 13, *Standard for the Installation of Sprinkler Systems*. The strategy DETECT FIRE then could be considered "standard." If, however, the water supply to the sprinkler system is inadequate, APPLY SUFFICIENT SUPPRESSANT would be considered "below standard" and, therefore, AUTOMATICALLY SUPPRESS FIRE as an output of an AND gate also would be considered "below standard."

Thus, the AND gate represents a situation where the chain is only as strong as its weakest link. An OR gate, on the other hand, is analogous to a pair of pants held up by both belt and suspenders. The pants will not fall down if either one breaks.

6-2.5 Step Five.

Proceed "up" the tree in this manner, qualifying each output on the basis of the quality of the inputs and the logic gate that connects them. When each element has been evaluated, the entire tree can be examined to determine where improvements should be made to meet fire safety objectives. Alternatively, in the design stage, move down the tree, making certain that strategies are present that will yield the desired objectives.

Evaluation should include reliability assessment, such as examining the effect of system failures on achievement of objectives. For example, what happens to the various outputs if the alarm system fails, i.e., SIGNAL NEED is rated "nonexistent?"

6-3 Example.

The use of the Fire Safety Concepts Tree in this manner is illustrated by examining fire prevention in a hypothetical computer facility. That is, consideration is given only to the PREVENT FIRE IGNITION branch of the tree, demonstrating how a partial tree can be used for evaluation of a particular strategy.

6-3.1 Objectives.

The first step is to identify the objectives. The general goal is to provide life safety, property protection, and operational continuity through prevention of the occurrence of fire. More specifically, in this example, the Fire Safety Concepts Tree is used to identify a "standard" level of fire prevention for a data processing center and to identify ways to raise the level of fire prevention in the facility to "above standard." Concern for the reliability of the fire prevention design also is addressed. In other words, the identified fire safety objectives are those implicit in national codes and standards, and the most effective ways to exceed this identified level of fire prevention are sought.

6-3.2 Heat-Energy Sources.

On the left side of the PREVENT FIRE IGNITION branch, there are two basic strategies or lower elements dealing with ignition sources. The first strategy is ELIMINATE HEAT-ENERGY SOURCE(S). In a computer facility, it is standard practice to prohibit heating appliances, smoking, and any other open flame-type of ignition source. Provisions should include a security program with adequate attention to the potential for arson. If these features are satisfactorily in place, this strategy can be assessed as “standard.”

To improve on this level of assessment necessitates elimination of every potential ignition source including electricity. It is, of course, not feasible to eliminate completely the possibility of electrical ignition sources in a computer facility where electrically powered equipment is the nature of the occupancy. It is, however, possible to reduce the likelihood of an ignition by controlling the use of electricity. One way to do this is to conform to NFPA 70, *National Electrical Code*, Article 645, “Electronic Computer/Data Processing Equipment.” If these measures are taken, the strategy CONTROL RATE OF HEAT-ENERGY RELEASE can be considered as “standard.” It would be technically possible, though perhaps not practical, to improve the value of this element by using an intrinsically safe electrical system such as described in ANSI/UL 913, *Intrinsically Safe Apparatus and Associated Apparatus for Use in Class I, II, and III, Division 1 Hazardous Locations* (an intrinsically safe electrical system is one that does not release sufficient energy to ignite the combustibles in the environment).

6-3.3 Fuel.

Consider the CONTROL FUEL branch of PREVENT FIRE IGNITION. Common combustibles in computer facilities include paper, plastic insulation on wiring, certain components or parts of equipment, and plastic media such as tape and disks. Section 4-1 of NFPA 75, *Standard for the Protection of Electronic Computer/Data Processing Equipment*, identifies materials and equipment that may be permitted in a computer room. Compliance with NFPA 75 can be considered as a “standard” level for the strategy ELIMINATE FUEL(S).

Parts of Chapter 5 of NFPA 75 address the limits of flame spread and flash point for materials used in computer equipment. Compliance with these requirements can be construed as a “standard” level of the strategy CONTROL FUEL PROPERTIES.

Avoidance of flammable gases and oxygen-enriched atmospheres can be considered as “standard” for CONTROL THE ENVIRONMENT, although these ordinarily are not concerns in a computer facility. An “above standard” strategy is a habitable atmosphere that does not support combustion, as suggested for spacecraft and similar occupancies.

6-3.4 Source-Fuel Interactions.

Control of heat transfer between ignition sources and combustibles is not a common strategy in computer facilities. It is very difficult to isolate combustible media and components from the electrical power without significant alteration of construction or procedures. For example, the electrical insulating properties of polylvinylchloride make it a most efficient material to have in contact with electrical conductors, even though it is combustible. Thus, all of the basic strategies under the CONTROL SOURCE-FUEL INTERACTIONS branch could be classified as “nonexistent.” Note that, even though certain valuable media are sometimes stored in a fire-resistive container, this is primarily a strategy for managing the exposed, which is not likely to contribute significantly to preventing ignition.

6-3.5 Results.

The results of this process are shown in Figure 6-3.5. Now that a qualitative assessment of each lowest element in the PREVENT FIRE IGNITION branch has been made, it is possible to follow the procedures of steps 3 and 4 to evaluate the results. Input of a “standard” element (in this case, there are two) to CONTROL HEAT-ENERGY SOURCE(S) indicates that the output element also is “standard.” On the other side, “standard” inputs also indicate that CONTROL FUEL is “standard.” With only “nonexistent” elements as inputs, CONTROL SOURCE-FUEL INTERACTIONS is “nonexistent.” Then, the final OR gate leading to PREVENT FIRE IGNITION has two “standard” inputs so the output is “standard” (only one “standard” input is needed to be considered “standard,” since it is an OR gate).

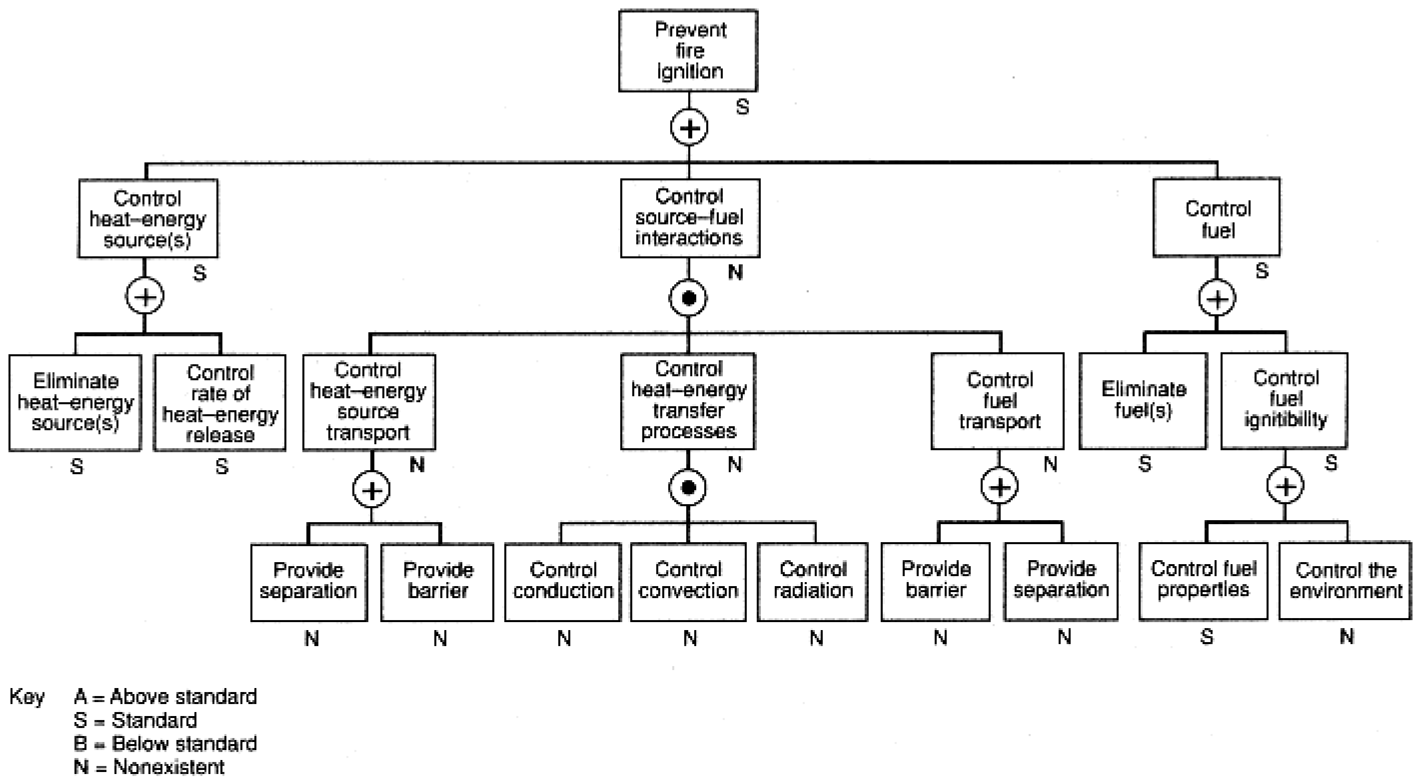


Figure 6-3.5 Fire prevention in a computer facility.

The results shown on the diagram can lead to several conclusions:

(a) Prevention of fire in the computer facility meets a level arbitrarily identified as “standard,” and reliability is provided by redundant (duplicate) “standard” inputs to the OR gate that yield PREVENT FIRE IGNITION.

(b) A “standard” level of CONTROL SOURCE-FUEL INTERACTIONS provides a third degree of redundancy.

(c) Ways exist to improve certain elements to “above standard,” but all the current “standard” elements need to be improved to provide consistent reliability.

This same process could be applied to other branches or to the entire Fire Safety Concepts Tree. However, it is important to keep in mind that this approach is not a general solution to any fire problem. The Fire Safety Concepts Tree provides support for a specific decision. It is a tool for examining a particular situation to discover possible alternatives, but it does not condone such alternatives automatically. Each situation is unique, and the tree can be used to provide a structure for an analysis based on accepted principles of fire protection engineering.

Chapter 7 Additional Information

7-1 General.

In order to provide an understanding of each concept in the tree, additional information was appended to the Fire Safety Concepts Tree published in 1980. This information appears in three parts: a description of elements in the tree, a glossary of terms, and an administrative action guide.

7-2 Description of Elements in the Fire Safety Concepts Tree.

Descriptions of tree elements or concepts have been provided to help convey the intent of the Systems Concepts Committee. These descriptions are intended as a guide to the thinking that framed the tree and should not restrict alternative interpretation of the concepts if such alternative descriptions are based on appropriate fire protection engineering principles. For example, it might be appropriate to a specific application of the tree to define PREVENT FIRE IGNITION in terms of a flame height or a rate of heat release. At the same time, this is the only published source of definitions of these concepts and is, therefore, a step toward better communication through common understanding.

The Fire Safety Concepts Tree
(A Qualitative Guide to Fire Safety Strategies)

The following set of descriptions is presented to offer the Systems Concepts Committee's best guidance on the application of the Fire Safety Concepts Tree. It is not intended to force a narrow or singular interpretation on those who find sound value in a broader or otherwise more relevant application of the elements in the Tree. This system of definitions is consistent with the thinking that the committee applied in naming the elements and terms used.

It will be noted that some of the lower level Tree elements are not defined here, but the essential terms used therein are defined in the Glossary.

Description of Elements in the Fire Safety Concepts Tree

Accomplish by Administrative Action means to eliminate, *limit, control,* or accomplish other actions referenced in the Fire Safety Concepts Tree.

Apply Sufficient Suppressant (*automatically*) means to *automatically* perform *suppressive* action in response to *automatic* detection.

Apply Sufficient Suppressant (*to manually suppress)* means to *manually* perform *suppressive* action given response to the proper site.

Automatically Suppress Fire means to *automatically* perform actions on a *fire* process in order to *limit* the growth of or to extinguish the *fire*.

Cause Movement of Exposed means to initiate movement of the *exposed* to and along a safe path.

Communicate Signal means to transmit knowledge of a detected *fire* via human or *automatic* or a combination of human and *automatic* means to a responsible recipient of the information.

Confine/Contain Fire means to provide building construction features and built-in equipment in order to *limit* the *fire* or *fire products,* or both, to within the *barriers* surrounding the area where the *fire* originated.

Control Combustion Process means to *control* the inherent *fire* behavior.

Control Fire by Construction means to *control* the growth of the *fire* and the movement of *fire products* by performing actions involving building construction features and built-in equipment without intentionally acting upon the inherent *fire* process.

Control Fuel (Manage Fire) means to influence the combustion process by *pre-ignition control* of the inherent or situational characteristics of the *fuel*.

Control Fuel (Prevent Fire Ignition) means to *limit* the characteristics and uses of *fuel(s)*.

Control Fuel Distribution means to *control* the arrangement of the *fuel* within its environment.

Control Fuel Ignitibility means to *control* the ease of *ignition* of *fuels* that are present.

Control Fuel Properties means to *control* the inherent properties of the *fuel*.

Control Fuel Transport means to prevent the *fuel* from moving to a location where *ignition* can result.

Control Heat-Energy Sources means to *limit* the characteristics and uses of *heat-energy sources*.

Control Heat-Energy Source Transport means to prevent the *heat-energy source* from moving to a location where an *ignition* can result.

Control Heat-Energy Transfer Processes means to alter the rate(s) at which the *fuel(s)* receives heat by *control* of the *heat transfer* mechanisms, such that *ignition* cannot result.

Control Movement of Fire means to *control* the movement of *fire* or *fire products*, or both, by providing and (where a normal functional necessity) activating building construction features and built-in equipment.

Control Rate of Heat-Energy Release means to *control* the rate of thermal energy release of existing *heat-energy sources*.

Control Source-Fuel Interactions means to *control* the relationships of *source* and *fuel* so as to *limit* the *heat* communicated from the *source* to the *fuel* in order that *fuel* temperature remains below that required for *ignition*.

Control the Environment means *control* of the inherent or situational characteristics of the environment.

Decide Action means to determine a proper reaction given the communication of the existence of a *fire*.

Defend Against Fire Products means to *safeguard* the *exposed* using measures that prevent the presence of, or *control* the impact of, *fire products* at the *place*.

Defend Exposed in Place means to *defend* the *exposed* in the *place(s)* where they were located at the time of *ignition*.

Defend the Place (*of the exposed*) means to *defend* the *place* occupied by the *exposed*.

Detect Fire (to *manually suppress fire*) means to identify the presence of *fire* either by human observation or by *automatic* mechanism(s).

Detect Fire (*automatically*) means to identify the presence of *fire* without reliance on human observation.

Eliminate Fuel(s) means to eliminate all *fuel*.

Eliminate Heat-Energy Source(s) means to eliminate all places, materials, or objects at which thermal energy can originate or from which thermal energy can be transferred.

Limit Amount Exposed means to *limit* the maximum amount of *exposed*.

Limit Fuel Quantity means to *limit* the amount of *fuel* that potentially can become involved in *fire*.

Maintain Essential Environment means to ensure the sufficient prevention, removal, dissipation, or neutralization of adverse conditions, other than *fire* or *fire products*, or both, as experienced by the *exposed* within the *place*.

Manage Exposed means to coordinate measures directly involving the *exposed*.

Manage Fire means to coordinate measures for *control* of the *fire* or *fire products*, or both.

Manage Fire Impact means to coordinate measures to *limit* any harm directly or indirectly resulting from *fire* or *fire products*, or both.

Manually Suppress Fire means to *manually* perform actions on a *fire* process in order to *limit* the growth of or to extinguish the *fire*.

Move Exposed means to safely relocate the *exposed* to safety.

Prevent Fire Ignition means to prevent initiation of destructive and *uncontrolled burning*.

Provide Movement Means means to provide the facilities necessary for a safe path through which the *exposed* can be relocated.

Provide Safe Destination (for the *exposed*) means to provide a safe location to receive the *exposed*.

Provide Separation (*fuel* transport) means to provide and maintain a *separation* between the *fuel* and the *source* by measures acting only upon the *fuel*.

Provide Separation (*source* transport) means to provide and maintain a *separation* between the *source* and the *fuel* by measures acting only upon the *source*.

Provide Structural Stability means to maintain the effectiveness of building construction features and built-in equipment.

Respond to Site means to respond to the proper site from which to *manually* initiate suppressive action.

Restrict Movement of Exposed means to prevent movement of the *exposed* beyond the boundaries of the *defended place*.

Safeguard Exposed means to act upon the *exposed* and the immediate surroundings of the *exposed* to *protect* the *exposed* against *fire impacts*.

Suppress Fire means to perform actions on a *fire* process in order to *limit* the growth of or to extinguish the *fire*.

Vent Fire means to provide building construction features and built-in equipment that can *control fire* by removal of the *fire* or *fire products*, or both.

7-3 Glossary.

Italicized terms in the descriptions of Fire Safety Concepts Tree elements are defined in the glossary. As in the case of the descriptions, these definitions are subject to interpretation, but to a lesser degree.

Automatic (automatically) means occurring without need of human action.

Barrier means a material obstacle (as opposed to *separation*).

Burning means continuous combustion including smoldering.

Capacity (of a *place* or location) means the maximum number or amount of *exposed* that a *place* or location can accommodate.

Capacity (of a route or path) means the maximum flow rate of *exposed* that a route or path can handle.

Conduction means a transfer of heat from a region of higher temperature through a material by a molecular mechanism not involving bulk motion to a region of lower temperature.

Control means to *limit*, affect, or alter the referenced factor(s).

Convection means transfer of heat by bulk motion of a fluid induced by mechanical devices or by gravitational effects due to nonuniform temperatures in the fluid.

Defend, as used in the Tree, means to *safeguard* the *exposed* using only those measures that prevent or *control fire impact* on the location of the *exposed*, without acting on the *fire* itself (see *safeguard*).

Exposed means any or all of the items specified in the fire safety objectives (e.g., persons, pieces of property, activities, or other valuable considerations).

Fire means any instance of destructive and *uncontrolled burning*, including explosions.

Fire Impact is a term used to denote the direct or indirect results of *fire*.

Fire Products, as used in the Tree, means flame, heat, smoke, and gas.

Fire Safety means the measures taken to *protect* the *exposed* so as to satisfy a specified objective.

Fuel means a substance that yields heat through combustion.

Heat-Energy is a term used to indicate that only the thermal forms of energy are of concern.

Heat-Energy Source (*source*) means any *place*, material, or object at which *heat-energy* can originate or from which *heat-energy* can be transferred.

Heat-Energy Transfer Process means the exchange of thermal energy from the *source* to the *fuel* by the mechanisms of *conduction*, *convection*, or *radiation*, or all three.

Ignitibility means the ease with which *fuel* undergoes *ignition*.

Ignition means the momentary event when *fire* first occurs.

Immobilize means to fix in place, so that no movement can occur.

Limit means to prescribe a minimum or maximum size, quantity, number, mass, extent or other dimension.

Manage means to coordinate broadly-ranging available methods toward accomplishment of objectives.

Manual means employing human action.

Place means an area within designated boundaries containing *exposed*.

Protect means the use of any or all available measures to *limit fire impact*.

Radiation means the combined process of emission, transmission, and absorption of energy traveling by electromagntic wave propagation (for example, infrared radiation) between a region of higher temperature and a region of lower temperature.

Safe Destination means a *protected place* of adequate capacity.

Safeguard as used in the Tree, means to *protect* the *exposed* by using only those measures directly involving the *exposed*, without acting on the *fire* itself (see *defend*).

Separation means an intervening space (as opposed to *barrier*).

Source — See *Heat-Energy Source*.

Suppression means extinguishment or active *limitation* of *fire* growth.

Thermal Energy — See *Heat-Energy*.

Transport means the movement of either the *heat-energy source* or the *fuel*.

7-4 Administrative Action Guide (see Figure 7-4

). The Administrative Action Guide uses the logic format to show various ways to regulate or promote fire safety strategies. It is intended as a generalized guide to encourage any of the measures described in the Fire Safety Concepts Tree.

Administration Action Guide

The NFPA Fire Safety Concepts Tree is a branching chain of goal/means relationships. However, beyond the Tree, an infrastructure exists in the form of an administrative scheme or social organization that is necessary to achieve the means deemed appropriate by the Tree. Such an administrative structure is shown in Figure 7-4.

This administrative scheme could pertain to any means throughout the Tree, since it represents only a generalized conceptual scheme (entirely nontechnical) for facilitating a means to achieve goals.

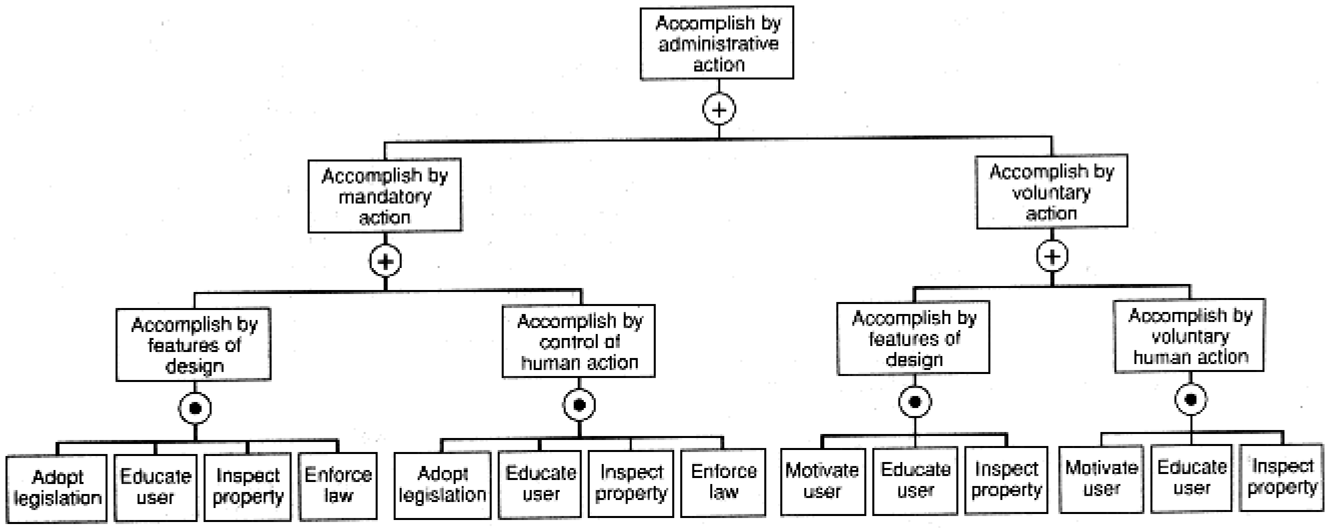


Figure 7-4 Administration action guide.

Chapter 8 Referenced Publications

8-1

The following documents or portions thereof are referenced within this guide and are considered a part of the recommendations of this document. The edition indicated for each reference is the current edition as of the date of the NFPA issuance of this document.

8-1.1 NFPA Publications.

National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.

NFPA 13, *Standard for the Installation of Sprinkler Systems*, 1994 edition.

NFPA 70, *National Electrical Code*, 1993 edition.

NFPA 75, *Standard for the Protection of Electronic Computer/Data Processing Equipment*, 1992 edition.

National Fire Protection Association "Fire Safety Concepts Tree," NFPA, Quincy, 1980.

8-1.2 Other Publication.

8-1.2.1 ANSI/UL Publication. Underwriters Laboratories Inc., 333 Pfingsten Road, Northbrook, IL 60062-2096.

ANSI/UL 913, *Intrinsically Safe Apparatus and Associated Apparatus for Use in Class I, II, and III, Division 1 Hazardous Locations*, 1988.

Appendix A Bibliography

This Appendix is not a part of the recommendations of this NFPA document but is included for informational purposes only.

This bibliography on the Fire Safety Concepts Tree is a collection of references to background documents from which the tree was developed and examples of uses and applications of the tree.

Brave, Ronald Melvin, "Developing a System Safety Approach for Decisions in Fire Protection Problems," Master's Thesis, George Washington University, 1970.

Butcher, E. Gordon and Alan C. Parnell, *Designing for Fire Safety*, Wiley, New York, 1983 "Methodology of Risk Analysis," pp. 168-169.

Cellentani, E. N. and William Y. Humphreys, "A Coordinated Detection/Communication Approach to Fire Protection," *Specifying Engineer*, May 1982, pp. 58-62.

Committee on Systems Concepts for Fire Protection in Structures, "Progress Report and Request for Comments," Annual Meeting Technical Committee Reports, National Fire Protection Association, Quincy, MA, 1974.

Committee on Systems Concepts for Fire Protection in Structures, "Information Report of Committee on Systems Concepts," Fall Meeting Technical Committee Reports, National Fire Protection Association, Quincy, MA, 1977.

Committee on Systems Concepts for Fire Protection in Structures, "Fire Safety Concepts Tree," Fall Meeting Technical Committee Reports, National Fire Protection Association, Quincy, MA, 1980.

General Services Administration, "International Conference on Fire Safety in High-Rise Buildings," GSA, Washington, DC, April 1971.

General Services Administration, "Reconvened International Conference on Fire Safety in High-Rise Buildings," GSA, Washington, DC, October 1971.

National Fire Protection Association, "Decision Tree," NFPA, Quincy, MA, 1974.

Quiter, James and William A. Webb, "Systems Based Risk Assessment Technique," paper presented at the symposium on Systems Applications for Fire Protection Engineers, University of Maryland, College Park, March 1981.

Roux, H. J., "Systems Approach to Fire Protection," paper presented at the NFPA First European Fire Conference, Geneva, Switzerland, October 1973.

Roux, H. J., "Systems Concepts for Fire Protection in Structures II," paper presented at the CIB Symposium on Fire Safety in Buildings: Needs and Criteria, Amsterdam, The Netherlands, June 1977.

Roux, H. J., "Update — NFPA Systems Concepts Committee," Proceedings of Symposium: "Systems Methodologies and Some Applications," Society of Fire Protection Engineers, Boston, 1980.

Thompson, Robert J., "A Progress Report of the NFPA's Systems Concepts Committee," *Fire Journal*, Vol. 68, No. 3, May 1974, pp. 26-27.

Thompson, Robert J., "Analyzing Firesafety Systems," *Fire Journal*, Vol. 71, No. 3, May 1977, pp. 60-62, 116.

Watts, J., "The Goal Oriented Systems Approach," NBS-GCR-77-103, National Bureau of Standards, Washington, DC, July 1977.

Watts, Jack, James A. Milke, John L. Bryan, Rachel Dardis, and Vincent Brannigan, "A Study of Fire Safety Effectiveness Statements," final report on USFA contract no. 7-35563, Department of Fire Protection Engineering, University of Maryland, College Park, January 1980.

Watts, Jack, "A Matrix Approach to Fire Safety," paper presented at the symposium: Systems Applications for Fire Protection Engineers, University of Maryland, College Park, March 1981.

Watts, Jack, "Fire Safety Concepts Tree User's Guide," Fire Safety Institute, Middlebury, Vermont, 1983.

Appendix B Fault Tree Analysis

This Appendix is not a part of the recommendations of this NFPA document but is included for informational purposes only.

According to Recht (1), fault tree analysis was developed in 1962 by H.A. Watson of Bell Telephone Laboratories. The technique was subsequently made famous by the Boeing Company in its application to the Minuteman Ballistic Missile Program (2).

Fault tree analysis uses a tree-like diagram to describe and analyze an undesired or "top" event, so-called because it is located at the top of the diagram, with "branches" of the tree extending downward from it. These branches connect the events or conditions that cause the top event to occur. The relationships of these causative events are shown by connecting lines that pass through one of two basic "logic gates"   the "AND" gate and the "OR" gate. The AND gate indicates that a "fault" will occur when all the causative events happen simultaneously. If any single event in a group of events can produce the fault, then these events are inputs to an OR gate.

Fault trees are produced by identifying a specific failure and examining the system in a logical, well-organized way to determine those events that can produce the failure. Alternatively, a desirable top event can be considered. A "success tree" is based upon analysis of requirements and alternatives needed to achieve a specified goal or objective. The NFPA Fire Safety Concepts Tree is a success-type tree.

Fault tree analysis requires intimate knowledge of the system being analyzed. It is often time consuming, but if performed in a thorough manner, it is revealing. It often leads to the discovery of combinations of factors that otherwise might not have been recognized as causative of the event analyzed. The tree becomes a record of the thought process of the analyst and serves as an excellent visual aid for communication with designers and management. More detailed descriptions of fault trees and fault tree analysis are found in references 3 through 5, which follow.

References

1. Recht, J. L., "Systems Safety Analysis: The Fault Tree," *National Safety News*, Vol. 93, No. 4, 1966.

2. Rodgers, William P., Introduction to System Safety Engineering, John Wiley, New York, 1971.

3. Lambert, Howard E., "Fault Trees for Decision Making in Systems Analysis," PhD Dissertation, University of California, Livermore, 1975.

4. Field, Patricia T., “Fault Tree Analysis,” Proceedings of Symposium: “Systems Methodologies and Some Applications,” Society of Fire Protection Engineers, Boston, 1980.

5. Vesely, W. E., F. F. Goldberg, N. H. Roberts, and D. F. Haasl, *Fault Tree Handbook* (NUREG-0492), Nuclear Regulatory Commission, Washington, DC, 1981.

Appendix C Logic Gates

This appendix is not a part of the recommendations of this NFPA document but is included for informational purposes only.

The plus and dot symbols used for OR gates and AND gates in fault trees and the Fire Safety Concepts Tree are standard symbols for these logic operations used in electronic circuit diagrams and Boolean algebra. They are derived from the algebra of probabilities. The flip of a coin is an example. To calculate the probability of a head *or* a tail, the probability of a head (0.5) is added to the probability of a tail (0.5), i.e., 0.5 + 0.5 = 1. Thus, the symbol for an OR operation is a plus symbol. To calculate the probability of first showing a head *and* then a tail if the coin is flipped twice, the probabilities are multiplied, i.e., (0.5) • (0.5) = 0.25; thus, the symbol for an AND gate is a dot signifying multiplication. Some additional examples of these logic gates are illustrated below.

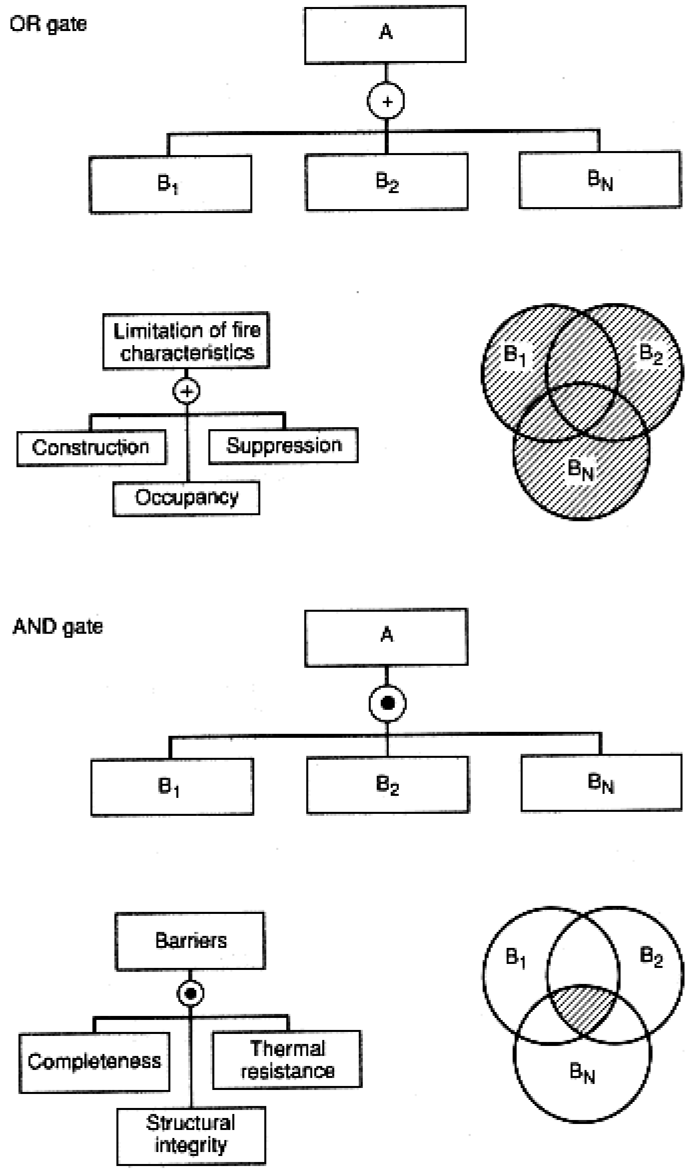


Figure C-1 Examples of logic gates.

1996 Edition

This first edition of NFPA 555, *Guide on Methods for Evaluating Potential for Room Flashover*, was prepared by the Technical Committee on Hazard and Risk of Contents and Furnishings and acted on by the National Fire Protection Association, Inc., at its Annual Meeting held May 20-23, 1996, in Boston, MA. It was issued by the Standards Council on July 18, 1996, with an effective date of August 9, 1996.

This edition of NFPA 555 was approved as an American National Standard on July 26, 1996.

Origin and Development of NFPA 555

This guide is the first document prepared by the Technical Committee on Hazard and Risk of Contents and Furnishings. It was developed in recognition that life safety and property protection can be enhanced by preventing the occurrence of flashover or, at least, decreasing its probability.

Technical Committee on Hazard and Risk of Contents and Furnishings

Gerald E. Lingenfelter, *Chair*
American Insurance Services Group Inc., NY

Ron Coté, *Secretary*
Nat'l Fire Protection Assn., MA
(Nonvoting)

Craig Beyler, Hughes Assoc., Inc., MD

John A. Blair, The DuPont Co., DE
Rep. T/C on Fire Tests/Society of the Plastics Industry

Richard W. Bukowski, U.S. Nat'l Inst. of Standards and Technology, MD

Gordon H. Damant, Inter-City Testing & Consulting Corp. of CA, CA

Paul Dillon, Southern College of Technology, GA
Rep. Sleep Products Safety Council

William E. Fitch, Omega Point Laboratories Inc., TX

Marcelo M. Hirschler, Mill Valley, CA

William E. Koffel, Jr., Koffel Assoc. Inc., MD

John W. Michener, Milliken Research Corp., SC
Rep. American Textile Mfrs. Inst., Inc.

Daniel J. O'Connor, Schirmer Engr Corp., IL
Rep. American Hotel & Motel Assn.

Patrick S. Saba, Westinghouse Savannah River Co., SC

T. Hugh Talley, Hugh Talley Co., TN
Rep. Upholstered Furniture Action Council/American Furniture Mfrs. Assn.

John J. Titus, MBS Fire Technology, Inc., MA

James J. Urban, Underwriters Laboratories Inc., IL

Alternates

David A. de Vries, Schirmer Engr Corp., IL
(Alt. to D. J. O'Connor)

Pravin D. Gandhi, Underwriters Laboratories Inc., IL
(Alt. to J. J. Urban)

Richard D. Gottwald, Society of the Plastics Industry, DC
(Alt. to J. A. Blair)

Thomas J. Ohlemiller, U.S. Nat'l Inst. of Standards and Technology, MD
(Alt. to R. W. Bukowski)

Kay M. Villa, American Textile Mfrs. Inst., Inc., DC
(Alt. to J. W. Michener)

Ron Coté, NFPA Staff Liaison

This list represents the membership at the time the Committee was balloted on the text of this edition. Since that time, changes in the membership may have occurred.

NOTE: Membership on a Committee shall not in and of itself constitute an endorsement of the Association or any document developed by the Committee on which the member serves.

Committee Scope: This Committee shall have primary responsibility for documents on fire hazard calculation procedures for use by other Committees in writing provisions to control the fire hazards of contents and furnishings. This Committee shall also provide guidance and recommendations to Committees in assessing the fire hazard of contents and furnishings. It shall establish classification and rating systems, request the development and standardization of appropriate fire tests, and identify and encourage necessary research as it relates to the fire hazards of contents and furnishings. It shall act in a liaison capacity between NFPA and the Committees of other organizations with respect to the hazard of contents and furnishings.

NFPA 555
Guide on Methods for
Evaluating Potential for Room Flashover

1996 Edition

NOTICE: An asterisk (*) following the number or letter designating a paragraph indicates explanatory material on that paragraph in Appendix A.
Information on referenced publications can be found in Chapter 7 and Appendix B. Detailed information on the references cited in brackets throughout the document can be found in B-1.2.3.

Chapter 1 Introduction

1-1 Scope.

1-1.1

This guide addresses methods for evaluating the potential for room flashover from fire involving the contents, furnishings, and the interior finish of a room. The methods addressed by this guide include prevention of ignition, installation of automatic fire suppression systems, control of ventilation factors, and limitation of the rate of heat release of individual and grouped room contents, furnishings, and interior finish.

1-1.2

The accuracy, precision, and relevance of this guide are a function of the accuracy, precision, and relevance of the data from the test methods and calculations used. The principles and concepts presented are among the most reliable available, and use of these principles and concepts can minimize the possibility of flashover but might not prevent it.

1-2 Purpose.

1-2.1

The purpose of this guide is to provide tools for those individuals or organizations attempting to implement methods to prevent the occurrence of flashover or, at least, to decrease its probability.

1-2.2

Any limitations on the availability of data, of appropriate test procedures, of adequate fire models, or of state of the art scientific knowledge places significant constraints upon the procedures described in this guide.

1-2.3

Some standard tests under controlled laboratory conditions are described. Such tests should not be deemed to establish performance levels for all situations.

1-3 Instructions for Use of This Guide.

See Figure 1-3.

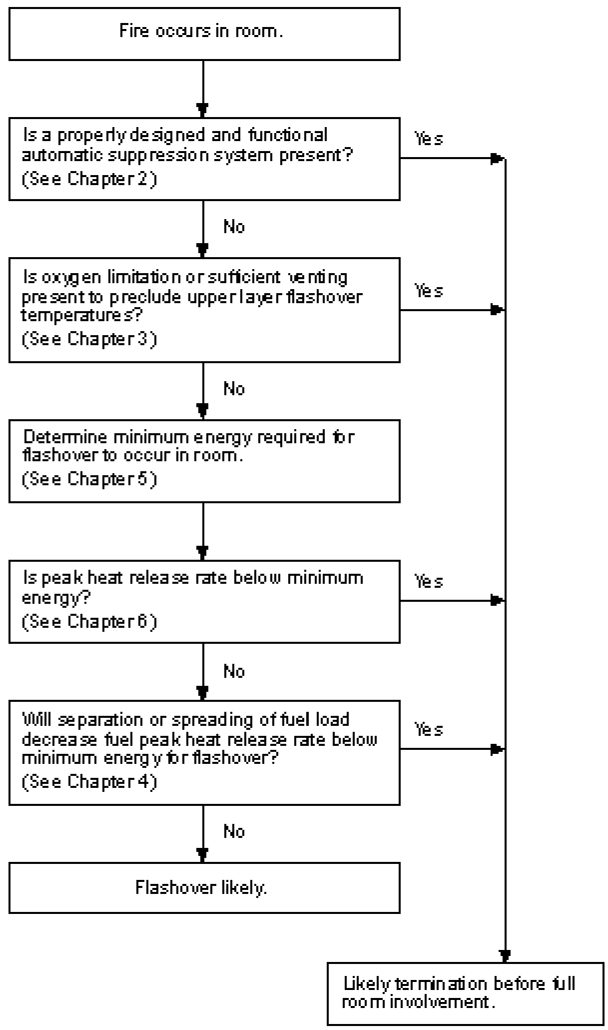


Figure 1-3 Flow chart for use of guide.

1-3.1

This guide is best used with a proper understanding of the various procedures it contains. Its core consists of five chapters that guide the user through analyses and procedures that are used to determine the likelihood of the compartment under investigation to reach flashover under fire conditions and to minimize the potential for flashover.

1-3.2

After conducting the analysis provided in each chapter, the user can make the determination of whether the potential for flashover has been decreased sufficiently or whether additional analysis is necessary. However, the user need not necessarily complete the analysis of each chapter before moving on to another chapter.

1-3.3

The first considerations in the analysis are the means of fire control, either via the existence of a properly designed and functional automatic suppression system or via techniques for smoke venting or reduction in oxygen availability. These issues are addressed in Chapter 2 and Chapter 3, respectively. A properly designed and functional system of either kind is likely to be a satisfactory means of reduction of potential for flashover.

1-3.4

If either of the following conditions exists, the user should conduct the analysis specified in Chapters 4 through 6:

(a) There is neither a properly designed and functional automatic suppression system, nor a similarly adequate method of reduction in oxygen availability; or

(b) Added precautions are desired.

1-3.5

Chapter 5 contains techniques for predicting flashover in compartments, irrespective of the contents, furnishings, or interior finishes involved. Chapter 6 indicates how the fire performance of contents, furnishings, or interior finishes can be used to assess the potential for flashover. Chapter 4 explains how the techniques in Chapter 6 can be expanded to include groups of items or products as fuel packages.

1-4 Definitions.

Contents and Furnishings. Any movable objects in a building that normally are secured or otherwise put in place for functional reasons, excluding the following:

(a) Parts of the internal structure of the building; and

(b) Any items meeting the definition of interior finish.

Flashover. A stage in the development of a contained fire in which all exposed surfaces reach ignition temperatures more or less simultaneously and fire spreads rapidly throughout the space. Flashover occurs when the surface temperatures of combustible contents rise, producing pyrolysis gases, and the room heat flux becomes sufficient to heat all such gases to their ignition temperatures. (*See Section 5-1.*)

Fuel Package. A fuel package is a grouping of one or more furnishing or contents items, or both, whose proximity is sufficiently close that the ignition of one item can be expected to cause the spread of fire to the remaining items in the fuel package. For a given group of items, there is no precise grouping that constitutes a fuel package. The purpose of the fuel package definition guidance provided in Chapter 4 is solely to facilitate the application of the methods described in Chapter 6 for estimating heat release rates.

Interior Finish. Exposed interior surfaces of buildings, excluding movable items that can be removed when occupants change. Interior finish includes interior wall and ceiling finish and interior floor finish. With respect to interior wall and ceiling finish, this means the exposed interior surfaces of buildings including, but not limited to, fixed or movable walls and partitions, columns, and ceilings. With respect to interior floor finish, this means the exposed floor surfaces of buildings including coverings that might be applied over a normal finished floor or stairs, including risers. Furnishings, which in some cases are secured in place for functional reasons, should not be considered as interior finish.

Item. A single combustible object within the compartment that is permanent or transient, movable, or fixed. An item can be a collection of combustible materials such as chairs, wastebaskets with contents, or a combustible wall or floor. A precise definition of an item is not generally possible or necessary.

Chapter 2 Automatic Suppression Systems

2-1 General.

Automatic suppression systems are the most widely used method for automatically controlling a fire. Consideration should be given to the utilization of an automatic suppression system for limiting the fire hazard potential in a room in order to reduce the probability of room flashover.

2-2 System Failure.

Although automatic suppression systems have an outstanding record of success, it is possible for such systems to fail. Failures are often due to weaknesses in the system that could have been avoided if appropriate attention had been given at the time of design, installation, or inspection. Issues pertaining to system integrity should be addressed carefully to increase the probability of successful operation of a suppression system. If a properly designed and functioning automatic suppression system is used in the design of a room, a fire that occurs in that room is likely to be controlled or terminated by the suppression system prior to full room involvement (flashover).

2-3 Hazard Protection.

Many standards and guides exist to aid a designer in the development of appropriate automatic suppression system design criteria for a wide range of occupancy types and hazards. Since the range and severity of occupancy types and fire types are rather broad, and since protection goals vary from minimal property protection to large-scale life safety, it is essential that hazards be adequately identified and evaluated and appropriate design guides be employed.

2-4 Automatic Suppression System Evaluation Considerations.

2-4.1

In those cases where a recognized design standard is not the basis for a suppression system design or where a unique or innovative suppression system approach is proposed, an evaluation of suppression system capabilities should be considered. Such an approach should include an analysis of the time to activation of the proposed suppression system compared to an evaluation of the "design fire" growth time with respect to the onset of flashover.

2-4.2

Significant factors affecting the ability of an automatic suppression system to prevent flashover include fire growth rate, quantity and arrangement of combustibles; enclosure characteristics; oxygen availability; fire detector (sprinkler) response characteristics; agent application rate (density); agent discharge characteristics, and duration of agent supply. Depending on the circumstances of the hazard and the level of protection required, some or all of the above factors might have to be evaluated to establish confidence in the ability of an automatic suppression system to reduce the probability of flashover significantly.

2-5 Design, Installation, and Maintenance.

The design, installation, and maintenance of automatic suppression systems are covered by a number of NFPA standards, including:

NFPA 12, *Standard on Carbon Dioxide Extinguishing Systems*.

NFPA 13, *Standard for the Installation of Sprinkler Systems*.

NFPA 13D, *Standard for the Installation of Sprinkler Systems in One- and Two-Family Dwellings and Manufactured Homes*.

NFPA 13R, *Standard for the Installation of Sprinkler Systems in Residential Occupancies up to and Including Four Stories in Height*.

NFPA 17, *Standard for Dry Chemical Extinguishing Systems*.

NFPA 25, *Standard for the Inspection, Testing, and Maintenance of Water-Based Fire Protection Systems*.

NFPA 2001, *Standard on Clean Agent Fire Extinguishing Systems*.

Chapter 3 Oxygen Availability and Ventilation

3-1 Considerations.

Oxygen availability or ventilation parameters can play a significant role in fire growth, the combustion process, and conditions that influence flashover potential in various types of fire scenarios.

3-1.2 Typical Fire Scenarios.

Normal air contains 20.9 percent oxygen, 79.1 percent nitrogen, and traces of other gases. In the combustion process, fuel combines with oxygen in air and the size of a resulting fire can be limited by either the amount of fuel or oxygen available for the combustion process. In most common fire scenarios, it should be reasonable to assume that oxygen is supplied to the fire from the surrounding air and that sufficient ventilation or air leakage paths are present to allow a continued supply of air and oxygen. The continued availability of air allows the growth of the fire and the continued burning of contents, furnishings, or interior finishes in a compartment.

3-1.3 Tightly Closed Compartments.

In fire scenarios, where a compartment is tightly closed or lacks sufficient ventilation or air leakage paths, the available oxygen is consumed in the combustion process until the oxygen volume concentration is reduced to between 8 percent and 12 percent. At these reduced oxygen levels, the flaming combustion of contents, furnishings, or interior finishes in a compartment can cease and the remaining oxygen will not be consumed. These conditions can prevent the fire from growing to a size sufficient to produce flashover conditions. However, sudden introduction of air (and oxygen) can result in a highly dangerous, rapid combustion of products of incomplete combustion called a backdraft. This might occur when doors are opened or windows are broken in the process of manual fire fighting.

3-1.4 Vented Scenarios.

In some fire scenarios, there is an abundance of ventilation in the form of a smoke/heat venting means or other exhaust mechanism that relieves sufficient heat and gases from a compartment, precluding the temperature rise conditions necessary to induce flashover [Hinkley, 1988].

3-2 Oxygen Consumption.

3-2.1 Principle of Oxygen Consumption.

It has been determined that the heat released per unit mass of oxygen consumed is nearly constant for most organic fuels. This value can be useful in air-limited fire scenarios to determine if the fire duration or maximum heat release rate predicted to cause flashover can be achieved. The value of heat released per unit mass oxygen consumed is 13.1 kJ/g (on an oxygen basis). The value of heat released per unit volume of oxygen consumed, $\Delta h_c \times \rho_{O_2}$, is 18.7 x 10^3 kJ/m^3 (on an oxygen basis), at 0°C. The corresponding values on an air basis are 3 kJ/g and 3.9 x 10^3 kJ/m^3 (also at 0°C).

3-2.2 Tightly Closed Compartments.

3-2.2.1 In tightly closed compartments, flashover potential exists only if the heat released by the fire can exceed the heat release rate necessary for flashover using the oxygen supply available in the compartment.

3-2.2.2 The duration of burning in a tightly closed compartment can be estimated for steady fires and for unsteady fires in which the heat release rate grows proportionally to the square of time (t-square fires). Estimations are based on the volume of the space and the heat release rate as shown in equation 3.1 for steady fires and equation 3.2 for unsteady fires.

Steady Fires:

$$t = \frac{V_{O_2}}{\dot{Q}}\left(\Delta h_c \times \rho_{O_2}\right) \qquad (3.1)$$

Unsteady (t-square) Fires:

$$t = \left(\frac{3V_{O_2}}{\alpha}\left(\Delta h_c \times \rho_{O_2}\right)\right)^{1/3} \qquad (3.2)$$

where:

t = Time (sec).

V_{O_2} = Volume of oxygen available to be consumed in combustion process [*see* 3-2.2.3] (m^3).

$\Delta h_c \times \rho_{O_2}$ = Heat release per unit mass of oxygen consumed (kJ/m^3).

$\dot{Q}$ = Heat release rate from steady fire (kW).

α = A constant governing the speed of fire growth (kJ/sec^3).

Values for typical fire growths are as follows:

Slow	2.93×10^{-3} kJ/sec^3	(0.00278 Btu/sec^3)
Medium	11.72×10^{-3} kJ/sec^3	(0.01111 Btu/sec^3)
Fast	46.88×10^{-3} kJ/sec^3	(0.04444 Btu/sec^3)

The maximum heat release rate for the unsteady (t-square) fire can be estimated as follows in equation 3.3:

$$Q = \alpha t^2 \qquad (3.3)$$

where t is the time, as determined from equation 3.2. The equations consider the energy associated with the mass (or volume) of oxygen consumed in the compartment and the energy is divided by the anticipated heat release rate of the fire.

3-2.2.3 It can be estimated that the maximum volume of oxygen available to be consumed in the combustion process is approximately half of the total available oxygen, since flaming combustion usually is not sustained once oxygen concentrations fall to the range of 8 percent to 12 percent.

3-2.3 Temperature Rise in Compartment.

3-2.3.1 With the times of fire duration determined from equations 3.1 and 3.2, equation 3.4, based on the compartment volume (containing air as an ideal gas at constant pressure with constant specific heat), can be used to estimate the temperature rise in the compartment and to determine if temperature conditions are sufficient for flashover [Milke & Mowrer, 1993].

$$\Delta T = T_o \left[\exp\left(Q_n / Q_o\right) - 1\right] \qquad (3.4)$$

3-2.3.2 In equation 3.4, Q_n is the net total heat released, which can be determined from equation 3.5 or 3.6, depending on the type of fire, and Q_o is the total ambient energy of air in the compartment, calculated using equation 3.7.

$$Q_n = \left(1 - X_L\right)\dot{Q}\left(\Delta t\right) \quad \text{(Steady fires)} \qquad (3.5)$$

$$Q_n = \left(1 - X_L\right)\frac{\alpha t^3}{3} \quad \text{(Unsteady [t − square] fires)} \qquad (3.6)$$

$$Q_0 = \rho_0 \; c_p T_0 \; V \qquad (3.7)$$

3-2.3.3 Description of Terms.

X_L = Fraction of heat loss to compartment boundaries (typical range, 0.6 to 0.95).

$\dot{Q}$ = Heat release rate of the fire (kW).

α = A constant governing the speed of fire growth (kJ/sec^3).

ΔT = Time period (sec).

ρ_0 = Density of air (kg/m^3).

c_p = Specific heat of air [kJ/(kg K)].

T_0 = Initial air temperature (K).

V = Volume of air in compartment (m^3).

3-2.4*

Other than the method of analysis outlined using equations 3.1 through 3.7, there are computer-based models that can evaluate the oxygen depletion, ventilation, and heat transfer effects that impact the flashover potential in tightly closed compartments.

3-3 Venting and Exhaust of Hot Smoke Layer.

3-3.1

Smoke produced from a flaming fire in a space is assumed to be buoyant, rising in a plume above the fire and striking the ceiling or stratifying due to temperature inversion. The space can be expected to begin to fill with smoke, with the smoke layer interface descending. The descent rate of the smoke layer interface depends on the rate at which smoke is supplied to the smoke layer from the plume. This assumes a two-zone model in which there is a distinct interface between the bottom of the smoke layer and the ambient air. For engineering purposes, the smoke supply rate from the plume can be estimated to be the air entrainment rate into the plume below the smoke layer interface.

3-3.2

The heat that is convected upward into the space or compartment results in an increase in temperature in the smoke layer in the space. The provision of vents or mechanical means of exhaust can serve to remove the hot gases from the rising fire plume, which increases the amount of air entrainment and promotes a lower smoke layer temperature. With appropriate consideration given to the amount of venting or exhaust and the expected fire size, the compartment smoke layer gas temperatures can be limited below the 600°C threshold indicator for flashover. Additional guidance and calculation methods can be found in NFPA 92B, *Guide for Smoke Management Systems in Malls, Atria, and Large Areas*, and NFPA 204M, *Guide for Smoke and Heat Venting*.

Chapter 4 Fuel Package Definition

4-1 Introduction.

This chapter provides methods for defining a fuel package for use in predicting heat release rates, compartment temperatures, and flashover potential.

4-2 Fuel Package.

The two aspects of fuel packages that are discussed in this chapter include the definition of a fuel package and the ignition of a fuel package due to heating by another fuel package within the compartment.

4-3 Defining Fuel Packages.

4-3.1 Guidance.

This section includes some simple definitions of fuel packages. These definitions should be used for guidance rather than as strict definitions.

4-3.1.1 Objects that are close enough in physical proximity so that continuous flame spread from item to item is possible generally are considered to be a fuel package. In such a situation, the ignition delays associated with object-to-object spread do not dominate the heat release rate history.

4-3.1.2 Items that are far enough away from other items or fuel packages that cannot be ignited by heat transfer from other items or fuel packages are not considered a part of a fuel package.

4-3.1.3 Items that are near enough to other items or fuel packages so that ignition of an item is possible due to heat transfer from other items or fuel packages are not included as part of a fuel package if any of the following apply:

(a) The ignition delay is sufficiently large that the peak heat release rate will have passed before the item reaches its peak burning rate; or

(b) The methods of Chapter 6 cannot be reasonably used if the item is included as part of a nearby fuel package; or

(c) Both 4-3.1.3(a) and (b) apply.

4-4 Methods/Tools.

4-4.1

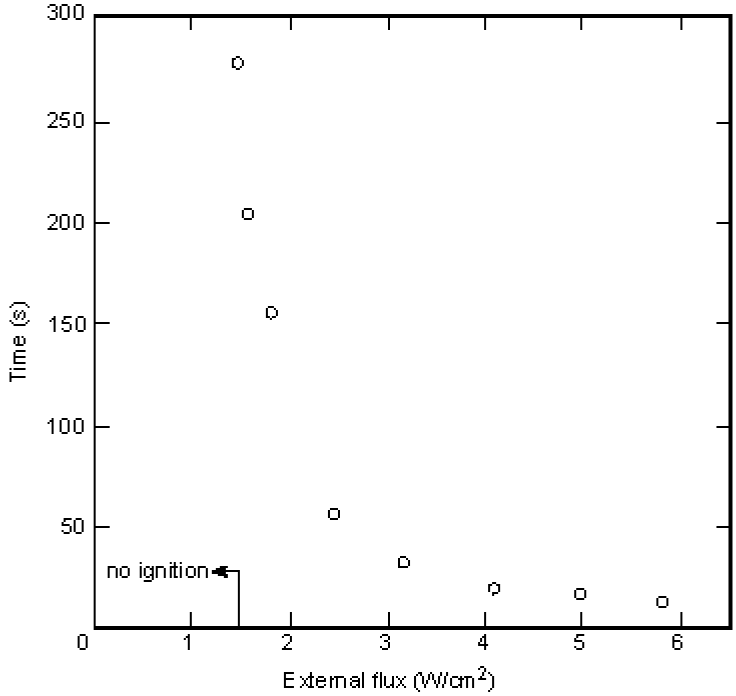
A set of analytical methods or tools is needed to provide a means for performing the evaluations embodied by the definitions in Section 4-3. In particular, methods are needed to predict the heating to ignition of materials contained within a fuel package as well as the radiative heat transfer to the material from other fuel packages or the hot gas layer. This section focuses on the radiative ignition of a material not in direct contact with a flame.

4-4.2 Radiative Ignition of Materials.

4-4.2.1* Many different models of radiative ignition of materials exist with varying levels of sophistication and usability. This section focuses on the method developed by Quintiere and Harkleroad [Quintiere & Harkleroad, 1985]. As with many of the available models, this model assumes that surface temperature can be used as a criterion for piloted ignition. This directly implies that ignition cannot occur if the radiant heat flux is less than a critical heat flux, $\dot{q}''_{o,ig}$. The ignition time, t_{ig}, varies with radiant flux above this critical flux. Based on a very simple heat transfer model, the time to ignition is determined as follows by equation 4.1:

$$t_{ig} = \left(\frac{\dot{q}''_{o,ig} / \dot{q}''_e}{b} \right)^2 \qquad (4.1)$$

where $\dot{q}''_e$ is the incident radiative heat flux and b is related to the thermal properties of the material. This data normally is obtained using the LIFT apparatus (ASTM E 1321, *Standard Test Method for Determining Material Ignition and Flame Spread Properties*) but also can be obtained using the cone calorimeter (ASTM E 1354, *Standard Test Method for Heat and Visible Smoke Release Rates for Materials and Products Using an Oxygen Consumption Calorimeter*). Figure 4-4.2.1 illustrates the ignition behavior of one type of fiberboard using this method [Quintiere & Harkleroad, 1985]. This method is valid for constant values of the incident heat flux, $\dot{q}''_e$. More general methods are also available in the referenced literature.



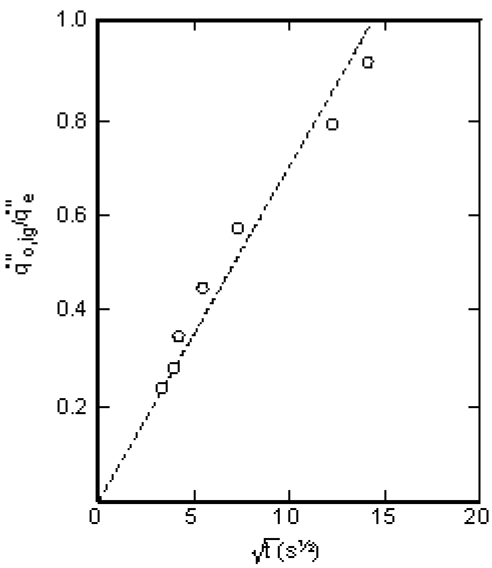


Figure 4-4.2.1 Ignition behavior of a particular type of fiberboard.

4-4.2.2 Equation 4.1 is based on a model of surface temperature (T_s) rise during heating given by equation 4.2 as follows:

$$T_s - T_0 = \left(\dot{q}''_e / h\right) F(t) \tag{4.2}$$

Where F(t) is determined from equation 4.3 or 4.4 as follows:

$$F(t) = 2ht^{1/2} / (\pi k\rho c)^{1/2} \quad \text{for } t < t_m \tag{4.3}$$

$$F(t) = 1 \quad \text{for } t \geq t_m \tag{4.4}$$

with t_m being the time necessary for equilibration of the surface temperature.

4-4.2.3 The first regime, for $t < t_m$, is modeled assuming no heat losses, while the second regime, for $t \geq t_m$, is modeled as a steady state. The ignition condition is derived by setting the surface temperature equal to the ignition temperature. The critical flux for ignition, $\dot{q}''_{o,ig}$, is defined by the flux necessary to reach the ignition temperature when $t \geq t_m$. Equation 4.1 is developed from the use of these considerations.

4-4.2.4 The product of the thermal conductivity, k, the density, ρ, and the heat capacity, c, is a fundamental material property often described simply as "kρc." Because of the simplifying assumptions used, the value kρc derived from LIFT (ASTM E 1321, *Standard Test Method for Determining Material Ignition and Flame Spread Properties*) or cone calorimeter (ASTM E 1354, *Standard Test Method for Heat and Visible Smoke Release Rates for Materials and Products Using an Oxygen Consumption Calorimeter*) data is to be regarded as an effective $k\rho c$ and should not be expected to be equal to the $k\rho c$ derived from methods used to measure these heat transfer properties.

4-4.3 Radiative Heating.

4-4.3.1 In order to evaluate the ignition of a material contained in a target fuel package, the radiative heat flux to the material from other fuel packages and the hot layer need to be determined. A number of methods can be used to make this determination.

4-4.3.2 The radiative heat fluxes generated by a range of fuel packages over a range of distances from the fuel package have been investigated [Babrauskas, 1981-82]. Based on knowledge of the burning rate of the radiating fuel package, the heat flux at specific distances from the fuel package can be estimated. Incident flux levels of 10 kW/m^2, 20 kW/m^2, and 40 kW/m^2 are defined as critical flux for ignition of general fuels and are described as easy, normal, and difficult to ignite, respectively. As noted in 4-4.2, the heat flux and duration of radiative exposure determine if ignition can occur.

4-4.3.3 Equations 4.5, 4.6, and 4.7 are used to determine the critical rate of heat release necessary to enable a burning object to ignite a target object that is classified as easy, normal, or hard to ignite, respectively, at a distance, D:

$$\dot{Q} = 30 \times 10^{\left(\frac{D+0.08}{0.89}\right)} \tag{4.5}$$

$$\dot{Q} = 30\left(\frac{D + 0.05}{0.019}\right) \qquad (4.6)$$

$$\dot{Q} = 30\left(\frac{D + 0.02}{0.0092}\right) \qquad (4.7)$$

where:

$\dot{Q}$ = Heat release rate (kW).

D = Distance (m).

If the rate of heat release of this burning object is increasing, the time at which the fire's rate of heat release is first reached is the time to ignition of the target object.

4-4.3.3.1 Equations 4.5, 4.6, and 4.7 are plotted in Figure 4-4.3.3.1. This graph can be used as a solution by reading up the appropriate curve to locate the separation distance and then finding the corresponding critical rate of heat release.

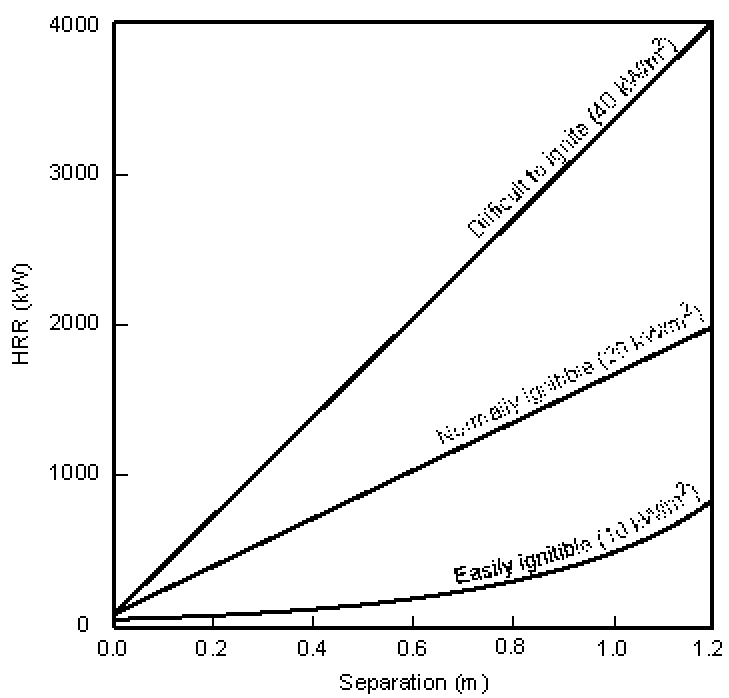


Figure 4-4.3.3.1 The inverse equation — separation distance versus rate of heat release.

4-4.3.3.2 Separation distance values of 140 cm, 90 cm, and 40 cm for easy, normal, and hard to ignite objects, respectively, represent distances beyond which the target objects are not considered part of the fuel package.

4-4.3.4 Two simple methods for evaluating radiation from pool fires to targets outside the flame have been developed [Mudan & Croce, 1988; Shokri & Beyler, 1989]. While these methods are based on pool fire test data, they can be applied to fuel packages. No studies have been performed to validate these methods where applied to furniture items. The pool fire data include diameters of 1 m to 50 m. Most fuel packages are at the low end of this range. The procedures for these methods are outlined below. Both methods model the flame as a cylindrical radiator with a specified emissive power. Configuration factors are then employed for the radiant heat flux calculation. The two methods differ only in their flame radiator height expressions and emissive power expressions.

4-4.3.4.1 The radiator is described as a cylinder with a radius determined by the size of the base of the fuel package. The height of the radiator is determined by a flame height correlation. Table 4-4.3.4.1 shows the flame height expressions used in the two models. The emissive powers used in the two models are given in Table 4-4.3.4.1 and are illustrated in Figures 4-4.3.4.1(a) and (b). The radiant flux to the target from the fuel package, $\dot{q}''_{r,fp}$, is determined by equation 4.8 as follows:

$$\dot{q}''_{r,fp} = F_{fp-dt}\,E \qquad (4.8)$$

where F_{fp-dt} is the configuration factor between the cylindrical radiator (fuel package) and the target, and E is the emissive power of the radiator.

Table 4-4.3.4.1 Flame Height and Emissive Power

	Mudan and Croce (1988)	Shokri and Beyler (1989)
Flame Height (m)	$H = 420\left(\frac{\dot{Q}}{\rho_a \Delta H_c \sqrt{gD}}\right)^{0.61}$	$H = 0.23\dot{Q}^{2/5} - 1.02\,D$ [m,kW]
Emissive Power (kW/m²)	$E = 140\left(e^{-0.12D}\right) + 20\left(1 - e^{-0.12D}\right)$ [m, kW]	$E = 58\left(10^{-0.00823D}\right)$ [m,kW/m²]

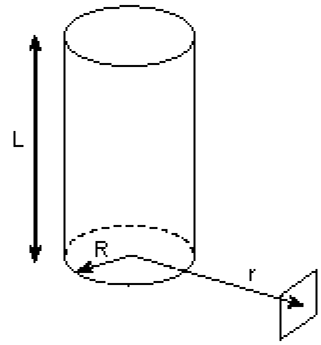
$$F_{d1\text{-}2,V} = \frac{1}{\pi S}\tan^{-1}\left(\frac{h}{\sqrt{S^2-1}}\right) - \frac{1}{\pi S}\tan^{-1}\sqrt{\frac{(S-1)}{(S+1)}} + \frac{Ah}{\pi S\sqrt{A^2-1}}\tan^{-1}\sqrt{\frac{(A+1)(S-1)}{(A-1)(S+1)}}$$

where

$$S = \frac{r}{R}, \quad h = \frac{L}{R},$$

$$A = \frac{(h^2 + S^2 + 1)}{2S}$$

$$B = \frac{1 + S^2}{2S}$$



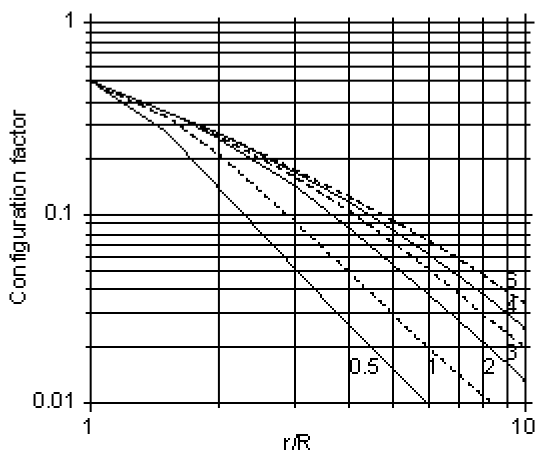
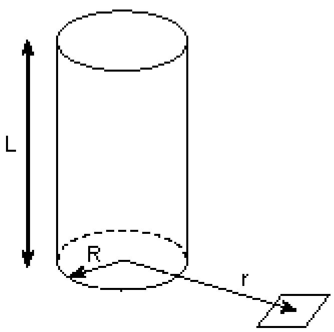


Figure 4-4.3.4.1(a) Configuration factor for a vertical target and a vertical cylindrical radiator (*adapted from C. L. Beyler*).

$$F_{d1\text{-}2,H} = \frac{(B - 1/S)}{\pi\sqrt{B^2 - 1}} \tan^{-1}\sqrt{\frac{(B+1)(S-1)}{(B-1)(S+1)}} - \frac{(A - 1/S)}{\pi\sqrt{A^2 - 1}} \tan^{-1}\sqrt{\frac{(A+1)(S-1)}{(A-1)(S+1)}}$$

where



$$S = \frac{r}{R}, \quad h = \frac{L}{R},$$

$$A = \frac{(h^2 + S^2 + 1)}{2S}$$

$$B = \frac{1 + S^2}{2S}$$

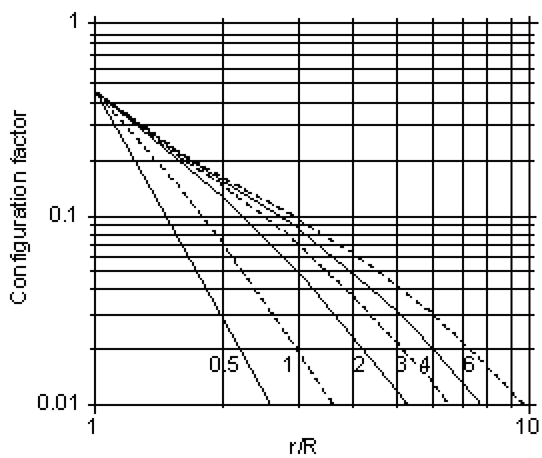


Figure 4-4.3.4.1(b) Configuration factor for a horizontal target and a vertical cylindrical radiator (*adapted from C. L. Beyler*).

4-4.3.4.2 The configuration factors for several relevant geometries are shown in Figures 4-4.3.4.1(a) and (b). These figures show the geometry, the equation, and a graph of the configuration factor. Configuration factors for other geometries related to those shown can be generated from the configuration factors provided, since configuration factors are cumulative. For instance, the worst case configuration at a given distance from the radiator is a target facing the flame at half the radiator height. This configuration factor can be created by considering the radiator to be composed of two cylinders, one above the target and one below. Since, in this case, the two cylinders are equal in size, the final configuration factor is simply twice the configuration factor for a radiator with a height equal to half the flame height.

4-4.3.5* The radiation from the hot gas layer can be estimated by methods similar to those described in 4-4.3.4 for the flame. The hot layer radiant can be modeled as a blackbody at the hot gas layer temperature, T_h. The configuration factor between the layer and the target, $F_{hL\text{-}dt}$, can be estimated based on the configuration factor between a flat rectangular radiator positioned at the location of the hot gas layer interface. The incident radiant heat flux from the layer to the target, $\dot{q}''_{r,h1}$, is determined by equation 4.9:

$$\dot{q}''_{r,h1} = F_{hL-dt}\, \sigma T_h^4 \qquad (4.9)$$

where σ is the Stefan-Boltzmann constant (5.67 x 10^{-11} kW/m^2 K^4) and T_h is the hot gas layer temperature in Kelvin (°C + 273). The worst case is a configuration factor of 1, which occurs if the target surface is facing the hot layer interface and is very close to the interface. The configuration factors for several relevant geometries are shown in Figures 4-4.3.5(a) and (b). These figures show the geometry, the equation, and a graph of the configuration factor. Configuration factors for other geometries related to those shown can be generated from the configuration factors provided, since configuration factors are cumulative. For instance, if the target is at the center of the room facing upward, the configuration factor is the sum of four configuration factors, one for each quadrant of the room. If the target is centered in the room, all four configuration factors are equal. If the target is close to the radiator, the maximum individual configuration factor is 0.25, and the maximum configuration factor is four times this value (i.e., 1.0, as previously discussed).

$$F_{d1\text{-}2} = \frac{1}{2\pi}\left[\frac{X}{\sqrt{1+X^2}}\tan^{-1}\left(\frac{Y}{\sqrt{1+X^2}}\right) + \frac{Y}{\sqrt{1+Y^2}}\tan^{-1}\left(\frac{X}{\sqrt{1+Y^2}}\right)\right]$$

where X = a/c and Y = b/c.

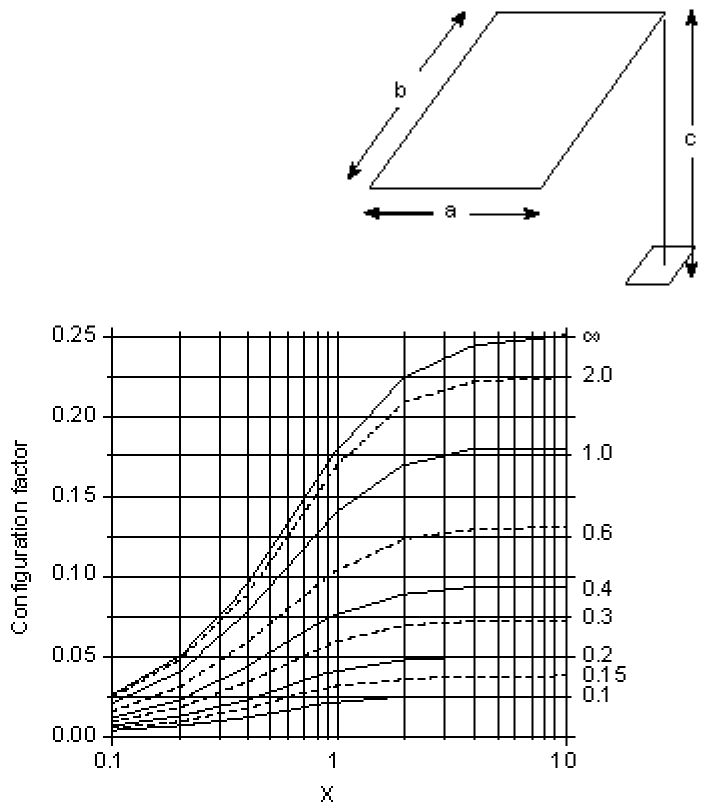


Figure 4-4.3.5(a) Configuration factor for one quadrant of the hot gas layer to a target facing the hot layer (*adapted from C. L. Beyler*).

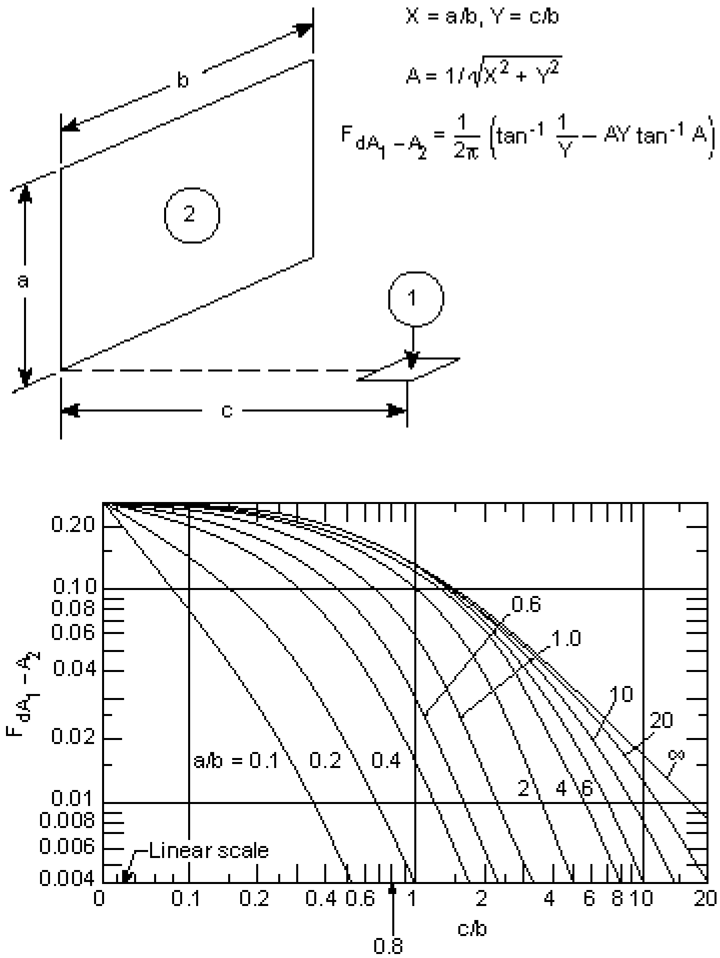


Figure 4-4.3.5(b) Configuration factor for one quadrant of the hot gas layer to a target not facing the hot layer (*adapted from E. M. Sparrow and R. D. Cess*).

4-4.3.6 The methods described in Section 4-4 are examples of those that can be used for this type of analysis. They might not be the best methods for every situation. Nothing in this section should be taken to exclude the use of better methods than those discussed.

Chapter 5 Predicting Flashover for Fire Hazard Calculations

5-1 Background.

5-1.1

The occurrence of flashover within a room is the ultimate signal of untenable conditions within the room of fire origin as well as a sign of greatly increased risk to other rooms within the building. A number of experimental studies of full-scale fires have been performed that provide an adequate but imprecise definition of flashover in terms of measurable physical properties. Computer simulations of the growth of a fire within a room are available.

5-1.2* Temperature.

Temperature rise in the upper layer of a compartment has been used as a criterion for indication of flashover. Documentation indicates that a gas temperature rise at flashover of 600°C is a reasonable expectation.

5-1.3* Heat Flux.

Heat flux at floor level also has been used as a criterion for indication of flashover. Documentation indicates that a heat flux at floor level at flashover of 20 kW/m^2 is a reasonable expectation.

5-2 Estimating Room Flashover Potential.

5-2.1*

The room flashover potential is best estimated by using Thomas' flashover correlation [Thomas, 1981], as provided in equation 5.1. The constants in equation 5.1 represent values correlated to experiments producing flashover.

$$\dot{Q} = 7.8 A_{room} + 378 \left(A_{vent}\sqrt{H_{vent}}\right)_{equivalent} \qquad (5.1)$$

$$A_{room} = A_{floor} + A_{ceiling} + A_{walls} - \left(A_{vents}\right)_{equivalent} \qquad (5.2)$$

$$W_{vent_{equivalent}} = \frac{\sum_{i=1}^{n}\left(A_{vent}\sqrt{H_{vent}}\right)_i}{\sqrt{H^3_{vent_{equivalent}}}} \qquad (5.3)$$

where $\dot{Q}$ = heat release rate of the fire (kW).

$A_{vent} = H_{vent} W_{vent}$ (m^2)

in which the product, $H_{vent} W_{vent}$, represents the dimensions of an equivalent vent defined by equation 5.1.

$H_{vent\ equivalent}$ equals the difference between the elevation of the highest point among all of the vents and the lowest point among all of the vents (m).

$W_{vent\ equivalent}$ equals the width of a virtual vent that has an area equivalent (for the purposes of determining flashover) to the combined area of all individual vents from the room of consideration (m).

5-2.2*

Alternative methods of estimating heat release at flashover also have been developed [Babrauskas, 1980a; Babrauskas & Krasny, 1985; McCaffrey et al., 1981; Quintiere, 1982].

5-2.3* General Information on Thomas' Correlation.

5-2.3.1 The formulation of the energy balance considered only the heat losses from the hot gas layer and heated walls to the cooler lower walls and floor surfaces. The term A_{room} actually should include all surfaces inside the room, exclusive of the vent area.

5-2.3.2 The fire area should not be subtracted from the floor area since the fire conducts and convects heat into the floor underneath the fuel footprint.

5-2.3.3 The equation is the same, irrespective of the location and form of the vent (a window or a door); however, the equation was developed from tests where venting was through a window as well as a door.

5-2.3.4 The equation does not address the external insulation of the walls. Thus, use of the equation for compartments with thin metal walls might be inappropriate.

5-2.3.5 The equation was developed from tests using fast-growth fires and has not been verified for fires that grow slowly or at moderate rates.

5-2.3.6 The equation was developed from experiments conducted in rooms not exceeding 16 m^2 in floor area. Extrapolation of the results from this equation for application to rooms with much larger floor areas might not be valid.

5-2.3.7 The equation is not valid for compartments without ventilation, since it would predict the possibility of flashover, which would be unlikely due to oxygen starvation of the fire.

5-2.3.8 The experiments used to develop this equation included the use of compartments with thermally thick walls and wood crib fires. The validity of the equation was later confirmed in gypsum-lined rooms using furniture fires [Parker & Lee, 1974]. Its validity for other surfaces or fire sources has not been fully established.

Chapter 6 Heat Release Rate Estimation Techniques

6-1 Introduction.

This chapter presents techniques for estimating the heat release rate for various individual items or products in a compartment, based on the results of direct measurements. Heat release rate is a crucial property for assessing fire safety because its maximum value is the numerical representation of the peak intensity of a fire. Therefore, estimates of heat release rate are critical in predicting whether flashover can occur in a compartment, based on the items or products contained in the compartment and the distances between them. Sections 6-2 through 6-8 present a hierarchy for the preferred techniques for such estimates.

6-2 Preferred Hierarchical Order.

6-2.1

The preferred hierarchical order indicates that the reliability of the results is likely to decrease as the order of technique descends from the optimal to other types. Tests on individual materials and comparative estimates are the techniques with the lowest reliability for assessing the potential for room flashover. The optimal technique is a full compartment test that includes items or products contained in it, with the distances between items and products that are identical to those in the compartment of interest. The applicable techniques are described in more detail in Sections 6-3 through 6-8. The preferred hierarchical order is as follows:

(a) A full compartment fire test, including all items expected to be contained within it;

(b) Full-scale fire tests on individual items;

(c) Tests on large-scale mock-ups of individual items;

(d) Bench-scale tests, using composite samples representative of the end-use composite assemblies;

(e) Bench-scale tests using individual materials rather than composites as samples;

(f) Use of estimation techniques for calculating heat release rate in the compartment as determined from the results of tests in 6-2.1(b) through (e). This might be done by one of the following:

1. Quantitative estimation techniques; or

2. Relative estimation techniques.

6-3 Full Compartment Fire Tests.

6-3.1

Ideally, the heat release rate from the combination of contents, furnishings, and interior finishes contained in a compartment is obtained by carrying out a full compartment fire test, wherein each major combustible item, product, or fuel package is included, replicating as much as possible the locations where the items are to be placed in the compartment under investigation. ASTM E 603, *Standard Guide for Room Fire Experiments,* provides proper guidance for the various choices that need to be made. These include information on operator safety and on the most appropriate experimental techniques for various measurements. This approach is best suited for cases where multiple compartments with very similar contents and distributions are to be constructed.

6-3.2

One of the most important issues that needs to be addressed by the designer of a full-scale test is the selection of an ignition source.

6-3.2.1 If the only objective is to ensure that flashover cannot occur with the existing combustible contents, the size of the ignition source used is of little importance, as long as it is not large enough to cause flashover on its own. An initial test should be carried out, with the ignition source as the only item present, to confirm that flashover does not occur in the absence of other combustible items. The objective of this test is extremely limited.

6-3.2.2 If the experiment is being carried out to determine the fire hazard inherent in the compartment being considered, the choice of ignition source and its location are crucial to the results of the test. They should be chosen to represent a realistic fire source in the occupancy under investigation.

6-3.2.3 If the experiment is being carried out in order to make a decision between various types of items or fuel packages of a particular type (e.g., an upholstered chair or a mattress), the ignition source should be sufficiently large to be a realistic fire source but small enough so that total consumption of the item is not inevitable. Therefore, the ignition source for such a full-scale test should not be so large as to overwhelm the product, irrespective of its fire performance.

6-3.3

There are some disadvantages in carrying out full compartment fire tests:

(a) They are costly, both in terms of actual expense and in terms of preparation;

(b) They are less susceptible to generalization, since small differences in item or fuel package location can have major effects on fire performance; and

(c) They cannot easily identify the effects of individual items or fuel packages on the overall fire performance of the whole compartment.

6-3.4

The ultimate objective of the tests should be to determine whether the compartment, as configured, is expected to reach flashover. If flashover is not reached, the results can be used for comparisons between items or products with similar functions but different construction or materials. Results from tests that do not reach flashover should be compared with the calculated heat release rates necessary for flashover or the upper gas layer temperatures necessary for flashover. The potential for flashover should be assessed in light of the reproducibility of test results and the impact of test result variability on achieving flashover conditions.

6-4 Full-Scale Tests on Individual Items or Fuel Packages.

6-4.1 General.

6-4.1.1 Full-scale tests have been developed for a variety of individual items, including wall finish, upholstered furniture, and mattresses. Full-scale tests also can be conducted on individual fuel packages in the same way in which they are conducted for individual items. The choice of ignition source and location are crucial to the results of the test. They should be chosen to represent a realistic fire source in the occupancy under investigation.

6-4.1.2 If it is possible that items or fuel packages could deteriorate through normal use or special situations, such as vandalism, additional tests might be necessary to evaluate the items after a suitable period of use or after the occurrence of such special situations (e.g., slashed cover and barrier).

6-4.1.3 Where quantitative precision or bias statements have not been developed for the full-scale tests used, appropriate compensation should be made for the lack of information regarding precision or bias.

6-4.1.4 Aesthetic design as well as geometric and spatial configuration can have significant influence on the ignition and burning properties of all items used for room contents, furnishings, and interior finishes. The issues of design, geometry, and spatial configuration are far too complex, important, and detailed to cover in this document. The references contained in Chapter 7 and Appendix B provide a resource on these subjects.

6-4.1.5* There are nearly an infinite number of material combinations that can be used in the construction of room furnishings. Heat release rate values for each of the composite items are likely to vary significantly and unpredictably from one composite type to another. Component materials can produce significantly different heat release values, depending on the presence of the other materials and on the physical design or geometry of the item. Thus, the value of design rules of thumb are limited and do not guarantee low rate of heat release values. Product testing therefore is necessary to determine the heat release rate for any given item.

6-4.2* Wall Finish.

Full-scale fire performance of wall finishes can be tested by means of NFPA 265, *Standard Methods of Fire Tests for Evaluating Room Fire Growth Contribution of Textile Wall Coverings,* or ISO 9705, *Fire Tests — Full Scale Room Fire Tests for Surface Products.*

6-4.3 Upholstered Furniture.

6-4.3.1 Full-scale fire performance of upholstered furniture can be tested by means of NFPA 266, *Standard Method of Test for Fire Characteristics of Upholstered Furniture Exposed to Flaming Ignition Source*, or ASTM E 1537, *Standard Test Method for Fire Testing of Real Scale Upholstered Furniture Items.*

6-4.3.2 Models exist that allow the effects of reradiation from room walls on heat release rate to be added to the results of the tests carried out in a furniture calorimeter. These effects are negligible unless the peak heat release rate of the furniture item exceeds 600 kW if tested in a furniture calorimeter or in a room of dimensions ranging from 2.5 m × 3.7 m to 3.1 m × 3.7 m, with a height of 2.5 m. If the heat release rate is that high, the importance of minor effects are probably of little consequence in a flashover prevention strategy [Parker et al., 1990].

6-4.4 Mattresses.

6-4.4.1 Full-scale fire performance of mattresses can be tested by means of NFPA 267, *Standard Method of Test for Fire Characteristics of Mattresses and Bedding Assemblies Exposed to Flaming Ignition Source*, or ASTM E 1590, *Standard Test Method for Fire Testing of Real Scale Mattresses*.

6-4.4.2 Models exist that allow the effects of reradiation from room walls on heat release rate to be added to the results of the tests carried out in a furniture calorimeter. These effects are negligible unless the peak heat release rate of the mattress exceeds 600 kW if tested in a furniture calorimeter or in a room of dimensions ranging from 2.5 m x 3.7 m to 3.1 m x 3.7 m, with a height of 2.5 m. If the heat release rate is that high, the importance of minor effects are probably of little consequence in a flashover prevention strategy.

6-4.5 Other Items.

6-4.5.1 Full-scale fire performance testing of other items should be performed by designing specialized tests for the item under consideration. Similar types of criteria should be developed to those documents referenced in 6-4.2, 6-4.3, and 6-4.4. Items or fuel packages of potential interest include pallets of storage commodities, case goods, and cleaning supplies.

6-4.5.2 It is recommended that ASTM E 603, *Standard Guide for Room Fire Experiments,* be used as a guide for developing the test and for making the measurements.

6-4.5.3 Currently, no standard full-scale fire test exists for floor finish (*see A-6-6.4*). In general, floor finish is not involved in fires until flashover is approached.

6-4.6

The use of tests on individual items has both advantages and disadvantages over testing all components of a compartment.

6-4.6.1 The advantages of testing individual items include:

(a) Lower cost;

(b) Greater specificity on the individual importance of the item under test; and

(c) Easier identification of the effects of composition or construction of the item under test on anticipated fire performance.

6-4.6.2 The major disadvantage of testing individual items is that the test is incapable of identifying the effect of the item being tested on the remaining items in the compartment.

6-4.7

In order to assess whether the compartment, as configured, is likely to reach flashover, tests should be carried out on all major items and the results should be combined. The simplest way to combine the results is by adding the peak heat release rates obtained from the individual items and comparing them with the predicted heat release rate necessary for flashover as determined from Chapter 5. This method can be improved by combining the concept of ignition of "second" items due to the radiation from burning items, based on the ignition propensity of each item and the distance between them [Babrauskas, 1981-82] (*see also 4-4.3.3*). A further improvement involves the use of an appropriate modeling technique, incorporating experimental fire test data, to predict the potential interactions between the burning items.

6-5 Tests on Large-Scale Mock-ups of Individual Items.

6-5.1

The effects of product composition on fire performance can be predicted to a considerable extent by carrying out large-scale fire tests on mock-ups of individual items (e.g., for upholstered furniture see ASTM E 1537, *Standard Test Method for Fire Testing of Real Scale Upholstered Furniture Items*). Such tests should be done in the same way as the tests on full-scale products.

6-5.2

This technique does not provide the investigator with an understanding of the effects of construction on fire performance.

6-5.3

Where testing upholstered furniture, it has been suggested that fire performance predictions can be improved by including factors associated with the mass, the type of frame, and the style of construction [Babrauskas, 1979, 1980b, 1983; Ames et al., 1992]. All of the aforementioned variables have important effects on heat release; insufficient quantitative information exists to allow estimates of the full-scale effects to be made.

6-5.4

Such testing should not be confused with testing on small-scale mock-ups, which very often is unsatisfactory because the effects of radiation from the flame are missing.

6-6 Bench-Scale Tests on Composite Samples.

6-6.1

Heat release and other fire test response characteristics of upholstered furniture or mattress composites in bench-scale can be determined by using an application of the cone calorimeter (ASTM E 1354, *Standard Test Method for Heat and Visible Smoke Release Rates for Materials and Products Using an Oxygen Consumption Calorimeter*), as specified in NFPA 264A, *Standard Method of Test for Heat Release Rates for Upholstered Furniture Components or Composites and Mattresses Using an Oxygen Consumption Calorimeter*, or ASTM E 1474, *Test Method for Determining the Heat Release Rate of Upholstered Furniture and Mattress Components or Composites Using a Bench Scale Oxygen Consumption Calorimeter*, at an incident radiant heat flux of 35 kW/m^2.

6-6.1.1 A number of studies have been conducted attempting to relate test results from bench-scale tests to fire performance in full-scale tests and some of these are discussed in the 6-6.1.2 through 6-6.1.8. It is important to note that the data published to date have failed to show consistent correlation between bench-scale and full-scale testing for fire test response characteristics.

6-6-1.2 Estimations of peak heat release rate in the full-scale furniture fire test specified in ASTM E 1537, S*tandard Test Method for Fire Testing of Real Scale Upholstered Furniture Items,* based on cone calorimeter (NFPA 264A, *Standard Method of Test for Heat Release Rates for Upholstered Furniture Components or Composites and Mattresses Using an Oxygen Consumption Calorimeter*, or ASTM E 1474, *Test Method for Determining the Heat Release Rate of Upholstered Furniture and Mattress Components or Composites Using a Bench Scale Oxygen Consumption Calorimeter*) data have been made. The initial work, done cooperatively by NIST and the California Bureau of Home Furnishings, suggested that the average (3-min) heat release rate is capable of predicting full-scale peak heat release rate (*see* Figure 6-6.1.2). The work suggested that there is a threshold at approximately 100 kW/m^2, so that systems that generated values below this threshold are not likely to develop self-propagating fires when they are made into actual furniture. Similarly, it suggested that average heat release rate values above 200 kW/m^2 are likely to result in furniture that can cause self-propagating fires. Equation 6.1 determines the non-self-propagating fire region found by that study as follows:

$$\dot{Q}(\text{full-scale}) = 0.75 \times \dot{Q}'' \qquad (6.1)$$

where $\dot{Q}$ (*full-scale*) is the peak rate of heat release in ASTM E 1537 (in kW), and $\dot{Q}''$ is the average (3-min) heat release rate per unit area in ASTM E 1474 at an incident flux of 35 kW/m^2 [Parker et al., 1990].

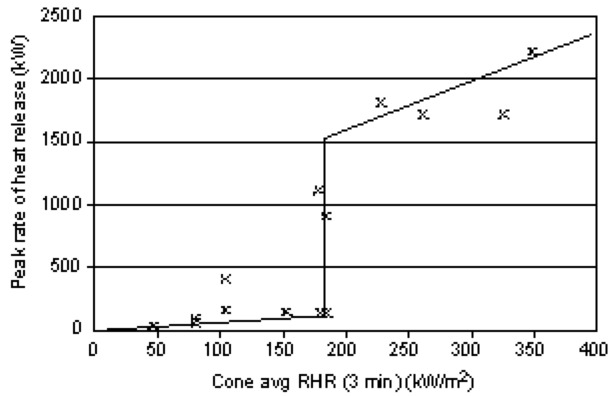


Figure 6-6.1.2 Relation of the results of full-scale ASTM E 1537 upholstered furniture tests with the average rate of heat release from the cone calorimeter (ASTM E 1354), at an incident flux of 35 kW/m2.

6-6.1.3 Another series of tests was carried out in which nine chairs were tested in ASTM E 1537, *Standard Test Method for Fire Testing of Real Scale Upholstered Furniture Items*, and the systems were also tested in the cone calorimeter (although not following the procedure in ASTM E 1474, *Test Method for Determining the Heat Release Rate of Upholstered Furniture and Mattress Components or Composites Using a Bench Scale Oxygen Consumption Calorimeter*). All systems had the same foam, interliner and chair construction but used different fabrics. Figure 6-6.1.3 illustrates a linear relationship between the peak (not average) heat release rate in the cone and the peak heat release rate in the full-scale test, with a regression correlation coefficient of 86 percent from the results of that study [Hirschler, 1995].

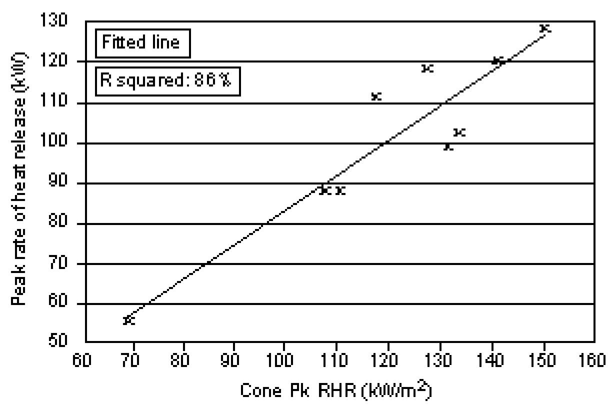


Figure 6-6.1.3 Relation of the results of one series of full-scale ASTM E 1537 upholstered furniture tests with the peak rate of heat release from the cone calorimeter (ASTM E 1354), at an incident flux of 35 kW/m^2. Correlation coefficient: 86%.

6-6.1.4 It should be stated, however, that such estimations are heavily dependent on the systems tested. Figure 6-6.1.4 indicates that, for three separate series of tests, the regressions found, although all linear, corresponded to different linear equations [Hirschler, 1995]

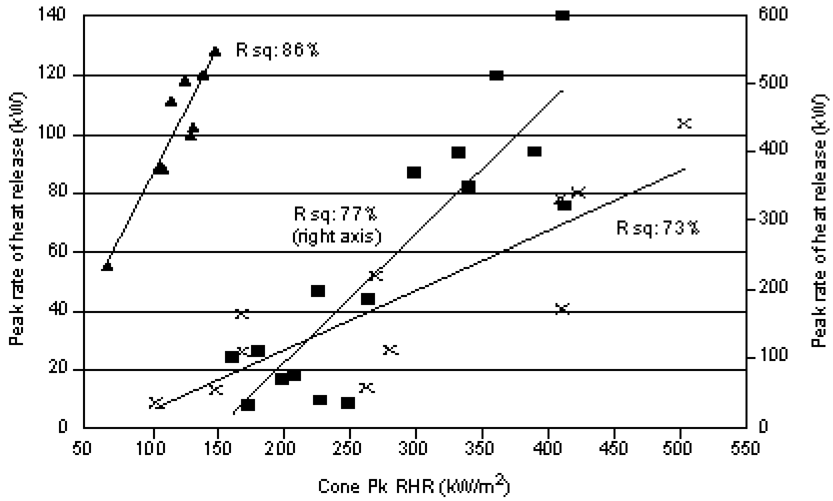


Figure 6-6.1.4 Relation of the results of three series of full-scale ASTM E 1537 upholstered furniture tests with the peak rate of heat release from the cone calorimeter (ASTM E 1354), at an incident flux of 35 kW/m^2. Correlation coefficients: 86%, 77% and 73%.

6-6.1.5 Other studies have also been made [Sundstrom, 1995; Forsten, 1995; Ohlemiller and Shields, 1995; ACT/DFA, 1995]. They have shown different types of estimations and have highlighted some difficulties.

6-6.1.6 Other studies in the cone calorimeter using incident heat fluxes of 25 kW/m^2 [Hirschler and Smith, 1990] and 30 kW/m^2 [Ames et al., 1993] have also been made.

6-6.1.7* Input from the cone calorimeter (NFPA 264A, *Standard Method of Test for Heat Release Rates for Upholstered Furniture Components or Composites and Mattresses Using an Oxygen Consumption Calorimeter*, or ASTM E 1474, *Test Method for Determining the Heat Release Rate of Upholstered Furniture and Mattress Components or Composites Using a Bench Scale Oxygen Consumption Calorimeter*) and from the LIFT apparatus (ASTM E 1321, *Standard Test Method for Determining Material Ignition and Flame Spread Properties*) can be used for predictions of furniture fire growth in a compartment.

6-6.1.8 Correlation between bench-scale and full-scale test results may be improved by incorporating factors that represent the effects of total mass, frame materials, frame style, and furniture design.

6-6.2 Bedding Materials.

6-6.2.1 Recent work has shown that estimates similar to those for upholstered furniture also apply to mattresses, relative to ASTM E 1474, *Standard Test Method for Determining the Heat Release Rate of Upholstered Furniture and Mattress Components or Composites Using a Bench Scale Oxygen Consumption Calorimeter*, and ASTM E 1590, *Standard Test Method for Fire Testing of Real Scale Mattresses* [Babrauskas, 1993].

6-6.2.2 Experience has shown that bedding materials can substantially affect heat release from mattresses, particularly where the mattress itself has demonstrated fairly poor fire performance.

Thus, in general, tests with mattresses and bedding are of interest mainly for those systems with fairly high heat release rate values.

6-6.3 Wall Lining Materials.

6-6.3.1* Several fire models can predict heat release and fire growth of wall linings in a compartment.

6-6.3.2 Standard application procedures for using the cone calorimeter with wall linings have not been fully developed, but some of the issues that need to be resolved regarding mounting techniques have been investigated [Fritz & Hunsberger, 1992].

6-6.4*

It has been shown that carpets can be tested in the cone calorimeter (NFPA 264, *Standard Method of Test for Heat and Visible Smoke Release Rates for Materials and Products Using an Oxygen Consumption Calorimeter*, or ASTM E 1354, *Standard Test Method for Heat and Visible Smoke Release Rates for Materials and Products Using an Oxygen Consumption Calorimeter*) at incident heat fluxes of 25 kW/m^2 to 30 kW/m^2 [Briggs et al., 1992; Ames et al., 1993; Hirschler, 1992a; Tomann, 1993]. Lower heat fluxes might be more appropriate for testing floor finish products.

6-7 Bench-Scale Tests on Individual Materials.

6-7.1

Tests on individual materials offer important input information to fire safety analyses resulting from products burning in a room. This is especially important in terms of the emitted heat release rate. However, information on materials cannot address the issue of the potential interaction (synergistic or antagonistic) between the various materials contained in a product.

6-7.2

Results of fire tests on materials, therefore, are useful either as a predictor of the relative performance of the materials (based on the assumption that interactions between materials are negligible) or as input into specific fire models developed to predict the fire performance of products from that of the component materials.

6-7.3

Two methods have been proposed as empirical relative analyses of overall material fire performance. Both methods require testing of materials in the cone calorimeter (ASTM E 1354, *Standard Test Method for Heat and Visible Smoke Release Rates for Materials and Products Using an Oxygen Consumption Calorimeter*).

6-7.3.1 The first method is an empirical relationship for predicting time to flashover from room wall lining materials in the same test as that covered by the Eurefic model specified in ISO 9705, *Fire Tests — Full Scale Room Fire Tests for Surface Products* (options 100 kW and 300 kW; three walls and ceiling covered). It uses input data from the cone calorimeter and equation 6.2, which follows:

$$t_{fo} = k_a \times \frac{t_{ign}\sqrt{\rho}}{\Sigma Q''_{Pk}} + k_b \qquad (6.2)$$

where t_{fo} is the predicted time to flashover in ISO 9705, (in sec), t_{ign} is the time to ignition in the cone calorimeter at an incident flux of 25 kW/m^2 (in sec), ρ is the density (in kg/m^3), $\Sigma\dot{Q}''_{Pk}$ is the total heat released per unit area during the peak period in the cone calorimeter at an incident heat flux of 50 kW/m^2, and k_a and k_b are constants [2.76×10^6 J (kg m)$^{-0.5}$ and –46.0 sec, respectively]. This method has been applied successfully to the Eurefic test data.

6-7.3.2 The other method is even simpler. It is a first order approximation for relative time to flashover in a room-corner scenario, as shown in equation 6.3:

$$t_{fo} \propto FPI = \frac{t_{ign}}{Pk\,\dot{Q}''} \qquad (6.3)$$

where the t_{ign}, the time to ignition (in sec), is measured in the cone calorimeter at an incident flux that is relevant to the scenario in question, Pk $\dot{Q}''$ is the peak heat release rate per unit area at that same incident flux (in kW/m^2), and FPI is the fire performance index (in sec m^2/kW). If the material does not ignite, t_{ign} can be assigned a value of 10,000 seconds. The incident heating flux to be used should be relevant to the fire scenario being investigated and is to be specified by the investigator. This method is useful as a relative indication of propensity to flashover and cannot be used quantitatively [Hirschler, 1992a, 1992b, 1992c]. However, it has been applied to two series of large-scale tests: FAA aircraft panels in a full-scale simulated aircraft interior [Lyon, 1994] and the Eurefic test data. Both test series were compared to cone calorimeter data at 540 kW/m^2. (*See Figure 6-7.3.2.*)

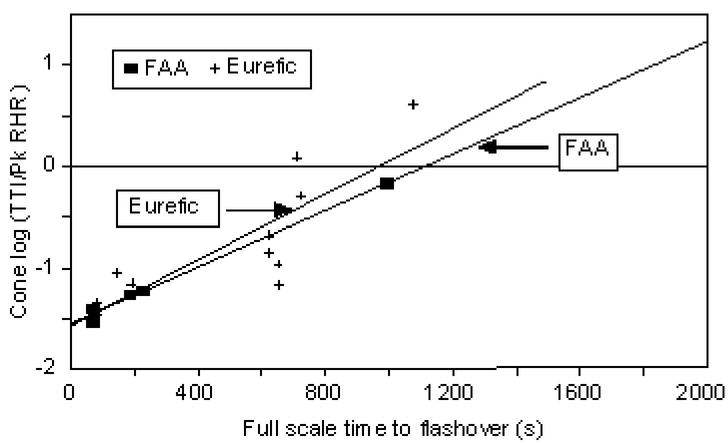


Figure 6-7.3.2 Comparison between full-scale times to flashover for FAA panels within an aircraft and for wall lining materials in ISO 9705, with the ratio of time to ignition to peak rate of heat release in the cone calorimeter (ASTM E 1354) at an incident flux of 50 kW/m^2.

6-8 Other Prediction Methods.

6-8.1*

Several methods exist that can be used as partial predictors of relative adequacy of performance of products and as additional tools.

6-8.2

Experienced observers are also capable of investigating which factors in the construction of upholstered furniture are most critical for potentially worsening fire performance to such an extent that a self-propagating fire can result.

Chapter 7 Referenced Publications

7-1

The following documents or portions thereof are referenced within this guide and should be considered part of the recommendations of this document. The edition indicated for each reference is the current edition as of the date of the NFPA issuance of this document.

7-1.1 NFPA Publications. National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.

NFPA 12, *Standard on Carbon Dioxide Extinguishing Systems*, 1993 edition.

NFPA 13, *Standard for the Installation of Sprinkler Systems*, 1996 edition.

NFPA 13D, *Standard for the Installation of Sprinkler Systems in One- and Two-Family Dwellings and Manufactured Homes*, 1996 edition.

NFPA 13R, *Standard for the Installation of Sprinkler Systems in Residential Occupancies up to and Including Four Stories in Height*, 1996 edition.

NFPA 17, *Standard for Dry Chemical Extinguishing Systems*, 1994 edition.

NFPA 25, *Standard for the Inspection, Testing, and Maintenance of Water-Based Fire Protection Systems*, 1995 edition.

NFPA 92B, *Guide for Smoke Management Systems in Malls, Atria, and Large Areas*, 1995 edition.

NFPA 204M, *Guide for Smoke and Heat Venting*, 1991 edition.

NFPA 264, *Standard Method of Test for Heat and Visible Smoke Release Rates for Materials and Products Using an Oxygen Consumption Calorimeter*, 1995 edition.

NFPA 264A, *Standard Method of Test for Heat Release Rates for Upholstered Furniture Components or Composites and Mattresses Using an Oxygen Consumption Calorimeter*, 1994 edition.

NFPA 265, *Standard Methods of Fire Tests for Evaluating Room Fire Growth Contribution of Textile Wall Coverings*, 1994 edition.

NFPA 266, *Standard Method of Test for Fire Characteristics of Upholstered Furniture Exposed to Flaming Ignition Source*, 1994 edition.

NFPA 267, *Standard Method of Test for Fire Characteristics of Mattresses and Bedding Assemblies Exposed to Flaming Ignition Source*, 1994 edition.

NFPA 2001, *Standard on Clean Agent Fire Extinguishing Systems*, 1996 edition.

7-1.2 Other Publications.

7-1.2.1 ASTM Publications. American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103-1187.

ASTM E 603, *Standard Guide for Room Fire Experiments*, 1994.

ASTM E 1321, *Standard Test Method for Determining Material Ignition and Flame Spread Properties*, 1993.

ASTM E 1354, *Standard Test Method for Heat and Visible Smoke Release Rates for Materials and Products Using an Oxygen Consumption Calorimeter*, 1994.

ASTM E 1474, *Standard Test Method for Determining the Heat Release Rate of Upholstered Furniture and Mattress Components or Composites Using a Bench Scale Oxygen Consumption Calorimeter*, 1992.

ASTM E 1537, *Standard Test Method for Fire Testing of Real Scale Upholstered Furniture Items*, 1994.

ASTM E 1590, *Standard Test Method for Fire Testing of Real Scale Mattresses*, 1994.

7-1.2.2 ISO Publication. International Organization for Standardization, c/o American National Standards Institute, 11 West 42nd Street, New York, NY 10036.

ISO 9705, *Fire Tests — Full Scale Room Fire Tests for Surface Products*, 1991.

7-1.2.3 Bibliography.

ACT/DFA, "Flammability Studies of Selected Fabrics, Flame-Blocking Barriers, and Polyurethane Foams in the California Technical Bulletin 133 and Cone Calorimeter Protocols." The Association of Contract Textiles and Decorative Fabrics Association, 1995.

Ames, S. A., Babrauskas, V., and Parker, W. J., "Upholstered Furniture: Prediction by Correlations," Chapter 15, *Heat Release in Fires,* Elsevier, London, UK, Eds. V. Babrauskas and S. J. Grayson, 519-544 (1992).

Ames, S. A., Rogers, S., and Murray, C., "Small and Full Scale Studies of Heat Release from Building Contents," *Proc Interflam 1993*, InterScience Communications, London, UK, 1993.

Babrauskas, V., "Full-Scale Burning Behavior of Upholstered Chairs," *NBS Tech. Note 1103*, National Bureau of Standards, Gaithersburg, MD, 1979.

Babrauskas, V., "Estimating Room Flashover Potential," *Fire Technology*, 16, 94-103, 112 (1980), (1980a).

Babrauskas, V., "Fire Tests and Hazard Analysis of Upholstered Chairs," *Fire Journal*, 74, 35-39 (1980), (1980b).

Babrauskas, V., "Will the Second Item Ignite?," *Fire Safety Journal*, 4, 281-292 (1981-82).

Babrauskas, V., "Upholstered Furniture Heat Release Rates: Measurements and Estimation," *Journal Fire Sci.*, 1, 9-32 (1983).

Babrauskas, V., "Bench-Scale Predictions of Mattress and Upholstered Chair Fires — Similarities and Differences," NISTIR 5152, NIST Internal Report, National Institute of Standards Technology, Gaithersburg, MD, March 1993.

Babrauskas, V., and Krasny, J., "Fire Behavior of Upholstered Furniture," *NBS Monograph 173*, National Bureau of Standards, Gaithersburg, MD, 1985.

Briggs, P. J., Harris, S. R., Ollerenshaw, M., Van Hees, P., and Van Wesemael, E., "Full Scale

Fire Testing of Carpets in Room/Corridor Scenarios and Comparisons with Small Scale Test Procedures," *Flame Retardants 1992*, (Ed. The Plastics and Rubber Institute), Elsevier, London, UK, 297-307, 1992.

Forsten, H. H., "Correlation of CAL 133 with Cone Calorimeter," *Proceedings of the International Conference on Fire Safety*, Volume 20, Ed. Hilado, C., 53-66, 1995.

Fritz, T. W., and Hunsberger, P. L., "Cone Calorimeter Test of Wall Coverings," *Proc. 1st. Int. Conf. on Fire and Materials*, Sept. 24-25, 1992, Crystal City, VA, InterScience Communications, London, UK, 117-123, 1992.

Hinkley, P. L., "Smoke and Heat Venting," Chapter 2-3, *The SFPE Handbook of Fire Protection Engineering*, National Fire Protection Association, Quincy, MA, 2/33-2/44 (1988).

Hirschler, M. M., "Electrical Cable Fire Hazard Assessment with the Cone Calorimeter," *Fire Hazard and Fire Risk Assessment*, ASTM STP 1150, Amer. Soc. Testing and Materials, Philadelphia, PA, Ed. M. M. Hirschler, 44-65 (1992), (1992b).

Hirschler, M. M., "Heat Release from Plastic Materials," Chapter 12a, *Heat Release in Fires*, Elsevier, London, UK, Eds. V. Babrauskas and S. J. Grayson, 375-422 (1992), (1992c).

Hirschler, M. M., "Smoke and Heat Release and Ignitability as Measures of Fire Hazard from Burning of Carpet Tiles," *Fire Safety Journal*, 18, 305-24 (1992), (1992a).

Hirschler, M. M., "Tools Available to Predict Full-Scale Fire Performance of Furniture," *Fire and Polymers II — Materials and Tests for Hazard Prevention* (ACS Symposium Series 599), 593-608, American Chemical Society, 1995.

Hirschler, M. M., and Smith, G. F., "Flammability of Sets of Fabric/Foam Combinations for Use in Upholstered Furniture," *Fire Safety Journal*, 16, 13-31 (1990).

Lyon, R. E., "Fire-Safe Aircraft Materials," *Fire and Polymers Intern. Symp.*, Amer. Chem. Soc. 208th Natl Mtg, Washington, DC, Aug. 21-23, Polymeric Materials: Science & Engineering Div. Preprints, 71, 26-27 (1994).

McCaffrey, B. J., Quintiere, J. G., and Harkleroad, M.F., "Estimating Room Temperatures and the Likelihood of Flashover Using Fire Data Correlations," *Fire Technology*, 17, 2, 98-119 (1981).

Milke, J. A., and Mowrer, F. W., "A Design Algorithm for Smoke Management Systems in Atria and Covered Malls," *Report No. FP93-04*, Univ. Maryland, Dept. Fire Protection Engineering, College Park, MD, May 1993.

Mudan, K. S., and Croce, P. A., "Fire Hazard Calculations for Large Open Hydrocarbon Fires," Chapter 2-4, *The SFPE Handbook of Fire Protection Engineering*, National Fire Protection Association, Quincy, MA, 2/45-2/87 (1988).

Ohlemiller, T. J., and Shields, J. R., "Behavior of Mock-Ups in the California Technical Bulletin 133 Test Protocol: Fabric and Barrier Effects," NISTIR 5653, National Institute of Standards and Technology, Gaithersburg, MD, May 1995.

Parker, W. J., and Lee, B. T., "Fire Build-Up in Reduced Size Enclosures," *Fire Safety Research, Proc. of a Symposium Held at the National Bureau of Standards*, Gaithersburg, MD on August 22, 1973. Eds. M. J. Butler and J. A. Slater, National Bureau of Standards, Gaithersburg, MD, NBS SP-411, 139-53 (1974).

Parker, W. J., Tu, K. M., Nurbakhsh, S., and Damant, G. H., "Furniture Flammability: An

Investigation of the California Technical Bulletin 133 Test. Part III: Full Scale Chair Burns," NISTIR 90-4375, National Institute of Standards Technology, Gaithersburg, MD, 1990.

Quintiere, J. G., "Smoke Measurements: An Assessment of Correlation Between Laboratory and Full-Scale Experiments," *Fire and Materials*, 6, 145-60 (1982).

Quintiere, J. G., and Harkleroad, M. T., "New Concepts for Measuring Flame Spread Properties," *Fire Safety: Science and Engineering,* ASTM STP 882, Ed. T.Z. Harmathy, American Society for Testing and Materials, Philadelphia, PA, 239-269 (1985).

Shokri, M., and Beyler, C. L., "Radiation from Large Pool Fires," *J. Fire Protection Engineering*, 1 (4), 141-149 (1989).

Sundstrom, B., Ed., CBUF Report, "Fire Safety of Upholstered Furniture — the final report on the CBUF research programme," EUR 16477 EN, European Commission, Measurements and Testing Report, Contract No. 3478/1/0/196/11-BCR-DK(30), Interscience Communications, London, UK, 1995.

Thomas, P. H., "Testing Products and Materials for their Contribution to Flashover in Rooms," *Fire and Materials*, 5, 103-11 (1981).

Tomann, J., "Comparison of Nordtest Fire 007, CEN Draft Proposal (Radiant Panel) and Cone Calorimeter Methods in the Fire Testing of Floor Coverings," *Fire and Materials*, 17, 185-90 (1993).

Appendix A Explanatory Material

This Appendix is not a part of the recommendations of this NFPA document but is included for informational purposes only.

A-3-2.4 The computer-based models are addressed in the following publications:

Bukowski, R. W., Peacock, R. D., Jones, W. W., and Forney, C. L., *Software User's Guide for the HAZARD I Fire Hazard Assessment Method, Volume 1*, NIST HB-1 16/1, National Institute of Standards and Technology, Gaithersburg, MD, 240, June 1989.

Bukowski, R. W., Peacock, R. D., Jones, W. W., and Forney, C. L., *Technical Reference Guide for the HAZARD I Fire Hazard Assessment Method, Volume 2*, NIST HB-1 46/11, National Institute of Standards and Technology, Gaithersburg, MD, 323, June 1989.

Cooper, L. Y., Forney, G. P., and Moss, W. F., *The Consolidated Compartment Fire Model (CCFM) Computer Code Application CCFM VENTS — Part IV; User Reference Guide*, NISTIR 43-15, National Institute of Standards and Technology, Gaithersburg, MD, July 1990.

Mitler, H. E., and Rockett, J. A., *User's Guide to FIRST. A Comprehensive Single-Room Fire Model*, CIB W14/88/22, National Bureau of Standards, Gaithersburg, MD, 1987.

Nelson, H. E., *FPETOOL: Fire Protection Engineering Tools for Hazard Estimation*, NISTIR 4380, National Institute of Standards and Technology, Gaithersburg, MD, 1990.

A-4-4.2.1 Table A-4-4.2.1(a) shows values of the critical heat flux, $\dot{q}''_{o,ig}$, b, which is related to the thermal properties of the material, and t_m, the time required for equilibration of the surface temperature, for a wide range of materials. Table A-4-4.2.1(b) illustrates that ignition properties within a generic category of materials can vary substantially. The values provided in the tables are intended as hypothetical results only. They provide a general indication of the magnitudes and ranges of the parameters. The materials tested were not sufficiently characterized to allow specific use of the data in particular applications.

Table A-4-4.2.1(a) Ignition Properties of Materials (Quintiere & Harkleroad, 1985)

	$\dot{q}''_{o,ig}$	b	t_m
Material	(W/cm^2)	($sec^{-0.5}$)	(sec)
Plywood, plain, 0.635 cm	1.6	0.07	190
Plywood, plain 1.27 cm	1.6	0.07	225
Plywood, FR, 1.27 cm	4.4	0.1	110
Hardboard, 6.35 mm	1	0.03	1190
Hardboard, 3.175 mm	1.4	0.05	420
Hardboard, gloss paint, 3.4 mm	1.7	0.05	468
Hardboard, nitrocellulose paint	1.7	0.06	306
Particle board, 1.27 cm stock	1.8	0.05	342
Douglas fir particle board, 1.27 cm	1.6	0.05	395
Fiber insulation board	1.4	0.07	205
Polyisocyanurate, 5.08 cm	2.1	0.36	8
Polystyrene, 5.08 cm	4.6	0.14	53
Polycarbonate, 1.52 mm	3	0.06	260
Foam, rigid, 2.54 cm	2	0.32	100
Foam, flexible, 2.54 cm	1.6	0.09	132
PMMA Type G, 1.27 cm	1.5	0.05	456
PMMA polycast, 1.59 cm	0.9	0.04	462
Carpet #1 (wool stock)	2.3	0.18	32
Carpet #2 (wool, untreated)	2	0.11	83
Carpet #2 (wool, treated)	2.2	0.12	72
Carpet (nylon/wool blend)	1.8	0.06	248
Carpet (acrylic)	1	0.06	250

Gypsum board, common, 1.27 cm	3.5	0.11	87
Gypsum board, FR, 1.27 cm	2.8	0.1	95
Gypsum board, wallpaper (S142M)	1.8	0.07	208
Asphalt shingle	1.5	0.06	306
Fiberglass shingle	2.1	0.08	161
GRP, 2.24 mm	1.6	0.09	132
GRP, 1.14 mm	1.7	0.06	279
Aircraft panel epoxy fiberite	2.8	0.13	57

Table A-4-4.2.1(b) Ignition Times of Different Materials in Cone Calorimeter

(All results are the mean of six replications)

Material	Thickness (cm)	Time to Ignition (sec)	Flux (kW/m^2)
Flexible Polyether-Type Polyurethane Foam			
1.2 PCF conv. foam	5.1	11	20
1.5 PCF conv. foam	5.1	22	20
1.8 PCF conv. foam	5.1	28	20
1.2 PCF 117 foam	5.1	38	20
1.5 PCF 117 foam	5.1	39	20
1.8 PCF 117 foam	5.1	37	20
3.0 PCF melamine foam	5.1	77	20
Rigid Polyether-Type Polyurethane Foam			
1.2 PCF MDI-based foam	5.1	40	20
1.5 PCF MDI-based foam	5.1	55	20
2.0 PCF MDI-based foam	5.1	95	20
Plywood			

AB douglas fir	1.27	330	35
AB douglas fir	1.91	410	35
BC douglas fir	1.27	160	35
BC douglas fir	1.91	180	35
Birch ICG	1.27	490	35
Birch ICG	1.91	550	35
BC yellow pine	1.27	90	35
BC yellow pine	1.91	100	35
BC yellow pine	1.27	125	35
BC yellow pine	1.27	140	35

A-4-4.3.5 Equation 4.9 assumes that the upper layer can be taken as a blackbody radiator. The emissivity is a function of the concentration of soot and gaseous combustion products, such as carbon monoxide, carbon dioxide, and water. It is assumed that, when the temperature of the upper layer is high enough to contribute significant radiative heat, the concentration of soot and gaseous combustion products is high enough for the upper layer to be optically thick, and an emissivity value of 1 is appropriate. This estimate is conservative with regard to upper layer contribution to ignition. This estimate can be reduced on the basis of a detailed radiation analysis.

A-5-1.2 Temperature. Observations include:

(a) In a series of full-scale compartment burnout tests (surface area of 55 m^2), the average upper gas temperature rises ranged from 198°C to 959°C, with an average of 584°C for fully developed fires in an enclosure [Harmathy, 1972a, b].

(b) In a study of the behavior of fully developed fires in single compartments by several laboratories, gas temperatures that were centrally measured at a point below the ceiling that was one-fourth the distance to the floor reached an average of 1070°C to 1145°C during three series of tests [Thomas & Heselden, 1972; Heselden, 1973].

(c) Flames exiting the doorway (a criterion for possible flashover) were observed during tests when the gas temperature measured approximately 10 mm below the ceiling reached 600°C [Hågglund et al., 1974]. When this criterion was applied to a series of full-scale mattress fires, two out of ten exhibited potential to flashover [Babrauskas, 1977]. These two mattress fires produced maximum gas temperatures of 938°C and 1055°C.

(d) In full-scale enclosure experiments, an average upper room temperature ranging from 450°C to 650°C provided sufficient radiation transfer to ignite crumpled newspaper at floor level in the compartment [Fang, 1975]. The average upper room gas temperature needed for ignition of the newspaper was 540°C ± 40°C [some temperatures were measured at the mid-height of the room (low values); temperatures measured 25 mm (1 in.) below the ceiling almost always exceeded 600°C].

(e) During tests in the living room of a mobile home, ignition of crumpled newspaper indicators was observed with upper room temperatures ranging from 673°C to 771°C [Budnick, 1978; Klein, 1978; Budnick & Klein, 1978, 1979]. In those tests where there was no full room involvement, maximum upper room temperatures ranged from 311°C to 520°C. Tests reaching flashover and starting in the master bedroom of a typically constructed, single-width mobile home showed peak temperatures ranging from 634°C to 734°C at flashover. Temperatures were measured 25 mm (1 in.) below the ceiling in the center of the room.

(f) Full-scale and quarter-scale tests of submarine hull insulation found ignition of newspaper on the floor at room air and doorway air temperatures of at least 650°C and 550°C, respectively [Lee & Breese, 1979]. For tests where flashover was not obtained, the maximum temperatures achieved were 427°C and 324°C, respectively. The authors note, however, that ignition of newsprint or a particular minimum doorway or interior air temperature is only a rough indicator of flashover because of the variation in the thermal and physical properties of crumpled newsprint, the nonuniform distribution of temperatures throughout the compartment, and the differences between tests of the combined thermal radiation from the smoke, the hot air, and the heated surfaces. The hot air inside the compartment usually became well mixed by the time it exited through the doorway. Thus, it was concluded that doorway temperatures might be more reliable flashover indicators than interior air temperatures.

(g) Maximum temperatures of over 800°C were observed during a flashover test of a urethane foam block chair [Babrauskas, 1979]. For tests of upholstered chairs where flashover did not occur, temperatures remained below 600°C.

(h) During a series of sixteen full-scale fire tests of residential basement rooms, ignition of paper flashover indicators at floor level with an average upper room gas temperature of 706°C ± 92°C indicated a possibility of flashover of 90 percent [Fang & Breese, 1980].

(i) During a study of burning wood cribs and plastic cribs in a room, a gap was found between low temperature fires (ceiling layer gas temperature < 450°C) and high temperature fires (ceiling layer gas temperature > 600°C) [McCaffrey & Rockett, 1977; Quintiere & McCaffrey, 1980]. The potential for flashover was identified by the fact that cellulose filter paper indicators ignited or were destroyed in the five cases (out of sixteen) involving high gas temperatures.

(j) Thomas' semiempirical calculation of the rate of heat release necessary to cause flashover in a compartment [Thomas, 1981] is based on a simple model of flashover. It predicts a temperature rise of 520°C and a blackbody radiation level of 22 kW/m^2 to an ambient surface that is not in the proximity of burning wood fuel at the predicted critical heat release rate necessary to cause flashover.

A-5-1.3 Heat Flux. Generalizations include:

(a) The concept of using the heat flux to exposed items within the fire room as a criterion for flashover was first suggested in 1974 [Parker & Lee, 1974]. It was stated that, at a heat flux of 20 kW/m^2 at floor level, cellulosic fuels in the lower part of the room are likely to ignite.

(b) Table A-5-1.3 provides the critical ignition fluxes for some materials for a 60-second exposure [Babrauskas, 1977]. The unpiloted values are probably more appropriate for determination of full room involvement, since the distance between the flames and the item to be ignited is considerable. A value of 20 kW/m^2 represents, according to W. K. Smith [Smith, date unknown], an unpiloted ignition time of approximately 180 seconds for box cardboard and is close to an ultimate asymptotic value.

Table A-5-1.3 Critical Ignition Heat Flux at a 60-Second Exposure

Material	Flux (kW/m^2)	
	Piloted	Unpiloted
Newspaper want ads	46	48
Box cardboard	33	43
Polyurethane foam	19	

(c) In one study of a series of room burns, strips of newsprint placed at floor level ignited at fluxes of 17 kW/m^2 to 25 kW/m^2, while 6.4-mm ($^1/_4$-in.) thick fir plywood ignited at 21 kW/m^2 to 33 kW/m^2 [Fang, 1975].

(d) In mobile home tests in which flashover occurred, the minimum total incident heat flux at the center of the floor was 15 kW/m^2 [Budnick, 1978].

(e) In submarine compartments, average heat fluxes at floor level of 17 kW/m^2 to 30 kW/m^2 at flashover were found [Lee & Breese, 1979].

(f) In basement room tests, substantial agreement was found between the time to ignition of newsprint flashover indicators and the time at which the incident heat flux measured at the center of the floor in the burn room reached a level of 20 kW/m^2 [Fang & Breese, 1980].

(g) Ignition of filter paper flashover indicators in tests with wood and plastic cribs was observed at a minimum heat flux of 17.7 kW/m^2, applied for at least 200 seconds [Quintiere & McCaffrey, 1980]. Under more controlled laboratory conditions, with radiant exposure to the same target configuration, the paper was charred black at 25 kW/m^2 and ripped at 120 seconds but only decomposed to a brown color under 15 kW/m^2. Thus, the criterion recommended was a heat flux of 20 kW/m^2.

A-5-2.1 Two alternative approaches to that of Thomas [Thomas, 1981] have been proposed to estimate the onset of flashover within a room.

A-5-2.2

(a) The first approach [Babrauskas, 1980a; Babrauskas & Krasny, 1985] is based on a simple combustion model with a flashover criterion of $\Delta T = 575°C$. It provides a simple rule to estimate the minimum heat release rate to produce flashover, as determined in equation A-5-2.2(a):

$$\dot{Q} = 0.6 A_{vent} \sqrt{H_{vent}} \qquad \text{[A-5-2.2(a)]}$$

where $\dot{Q}$ is the estimated rate of heat release, in MW, A is the door area, in m^2, and H is the door height (in m), with the $A_{vent}\sqrt{H_{vent}}$ product usually designated as the "ventilation factor."

(b) Equation A-5-2.2(a) results from assuming that the rate of heat release of the fire is proportional to the energy released per kilogram of air consumed (approximately 3.00 MJ/kg) and to the fraction of the maximum airflow into the compartment at the onset of flashover (an assigned value of 0.4).

(c) Equation A-5-2.2(a) has been shown to generate adequate agreement with experimental data. In two-thirds of the cases studied, the rate of heat release of the fire ranges between the results of the following two equations:

$$\dot{Q} = 0.45\,A_{vent}\sqrt{H_{vent}}$$ and [A-5-2.2(c)1]

$$\dot{Q} = 1.05\,A_{vent}\sqrt{H_{vent}}$$ [A-5-2.2(c)2]

A-5-2.3

(a) Another approach was based on a regression analysis in order to provide a correlation to predict upper layer gas temperature [McCaffrey et al., 1981; Quintiere, 1982]. Using data from over 100 experiments, the correlation found needed two dimensionless quantities, as shown in equation A-5-2.3(a):

$$\Delta T = 480\left[\frac{\dot{Q}}{\sqrt{g}\,C_p\rho_0 T_0\,A\sqrt{H}}\right]^{\frac{2}{3}}\left[\frac{h_k A_w}{\sqrt{g}\,C_p\rho_0 A\sqrt{H}}\right]^{-\frac{1}{3}}$$ [A-5-2.3(a)]

with ΔT in °C, and where ΔT is the temperature rise relative to ambient in °C, h_k is the effective heat transfer coefficient to ceilings/walls, A_w is the effective surface area for heat transfer, including door area, g is the gravitational constant, C_p is the specific heat of gas, ρ_0 is the ambient gas density, and T_0 is the initial ambient absolute temperature. A method for calculating the effective heat transfer coefficient, h_k, ranges has also been published [Pape & Waterman, 1976].

(b) The correlation coefficient between the experimental data and the predictions of equation A-5-2.3(a) ranges between 0.959 and 0.947, depending on whether the floor is included in the calculation of the wall area and the effective heat transfer coefficient.

(c) By substituting typical values for C_p, ρ_0 , T_0 , and a flashover criterion of ΔT = 500°C, equation A-5-2.3(a) can be reduced to equation A-5-2.3(c) as follows:

$$\dot{Q} = 0.61[h_k A_w A(h)^{1/2}]^{1/2}$$ [A-5-2.3(c)]

where $\dot{Q}$ is in MW, A_w and A are in m^2, h is in meters, and h_k is in $kW/(m^2\,K^{-1})$.

A-6-4.1.5 Several preliminary fire research projects have investigated the role of materials and product design characteristics on the flammability properties of room contents and furnishings [Babrauskas, 1981-82; Babrauskas et al., 1982; Babrauskas & Walton, 1986; Damant et al., 1989; Smiecinski et al., 1989; Schuhmann & Hartzell, 1989; Hirschler & Smith, 1990; Parker et al., 1990; Damant & Nurbakhsh, 1991; Hirschler & Shakir, 1991; Villa & Babrauskas, 1991; Gallagher, 1992; Barile, 1993; Grand et al., 1994].

A-6-4.2 NFPA *101®*, *Life Safety Code®*, includes some requirements on the use of NFPA 265, *Standard Methods of Fire Tests for Evaluating Room Fire Growth Contribution of Textile Wall Coverings*, while international specifications often reference ISO 9705, *Fire Tests — Full Scale Room Fire Tests for Surface Products*. Comparative details of the tests have been discussed recently [Hirschler, 1994]. The fire performance of wall finish is often assessed according to test results in the Steiner tunnel .test (NFPA 255, *Standard Method of Test of Surface Burning Characteristics of Building Materials*, or ASTM E 84, *Standard Test Method for Surface Burning Characteristics of Building Materials*). However, the results of this test are not suitable for use in the calculations cited in this document [Belles et al., 1988].

A-6-6.1.7 The Dayton University Furniture Fire Model takes input data from the cone calorimeter (ASTM E 1474, *Standard Test Method for Determining the Heat Release Rate of Upholstered Furniture and Mattress Components or Composites Using a Bench Scale Oxygen Consumption Calorimeter*) and the LIFT apparatus (ASTM E 1321, *Standard Test Method for Determining Material Ignition and Flame Spread Properties*) and uses it to predict the furniture fire growth and burnout in a room and the spread of combustion products (gases, smoke, heat) to other rooms [Dietenberger, 1992]. It is a zone model, associated with the FAST room fire model developed by the National Institute of Standards and Technology [Jones & Peacock, 1989], and has significant flexibility. It can simulate a piece of furniture with up to four cushions. However, this fire model is of high complexity and uses a complex set of data inputs. The LIFT apparatus is used in the Dayton University model to derive three parameters associated with flame spread: the thermal inertia [$k\rho c$ in units of $(kW/m^2\ K)^2$ sec], the ignition temperature T_{ig} in °C, and the flame heating parameter (F, in units of kW^2/m^3). It has been shown [Janssens, 1992a] that information on concurrent-flow flame spread (i.e., where the flame moves in the same direction as the prevalent wind) can be obtained directly from cone calorimeter data. On the other hand, opposed-flow flame spread probably still needs LIFT data, especially to determine the flame heating parameter. The flame spread rate, V_p, is calculated using equation A-6-6.1.6 (where T_s is the initial surface temperature in °C):

$$V_p = \frac{\Phi}{k\rho c\left(T_{ig} - T_s\right)^2} \qquad \text{(A-6-6.1.6)}$$

A-6-6.3.1 The Ohio State University (OSU) model is one of the first comprehensive fire models of a room corner fire, and it was developed at Ohio State University by E. E. Smith [Smith, 1972, 1977, 1978; Smith & Satija, 1983]. It predicts fire growth of wall linings on the basis of ignition, flame spread, and heat and smoke release data obtained from the OSU small-scale heat release calorimeter (ASTM E 906, *Standard Test Method for Heat and Visible Smoke Release Rates for Materials and Products*). The model has been shown to be adequate for wood materials but is less satisfactory for some other materials. The two main disadvantages of using this model include:

(a) Work on its development has been virtually discontinued; and

(b) The bench-scale apparatus on which it is based has been somewhat superseded by the cone calorimeter (ASTM E 1354, *Standard Test Method for Heat and Visible Smoke Release Rates for Materials and Products Using an Oxygen Consumption Calorimeter*).

The Eurefic method predicts time to flashover of wall linings as tested in the international room-corner test fire standard (ISO 9705, *Fire Tests — Full Scale Room Fire Tests for Surface Products*, options 100 kW and 300 kW; three walls and the ceiling are covered). Time to flashover also is predicted by the full-scale heat release rate curve as a function of time from the results of the cone calorimeter [ASTM E 1354 or ISO 5660, *Fire Tests — Reaction to Fire — Part 1: Rate of Heat Release from Building Products (Cone Calorimeter Method)*]. This model does not seek any results on factors such as airflow rates and hot layer depths, and it is, thus, a reasonably simple empirical approach. The model is based on three major assumptions:

(a) There is no direct relationship between the burning area growth rate and the heat release rate;

(b) The burning area growth rate is directly proportional to the ease of ignition (i.e., it is inversely proportional to the time to ignition in the cone calorimeter); and

(c) The history of the heat release rate per unit area at each location is the same in full scale as in small scale (cone calorimeter). Unfortunately, the full-scale test model does not have universal approval in the United States, where it is rarely used. The model is also known as the Eurefic model, because it was developed by the European Nordic countries within their particular program of research, with the objective of developing a unified classification system for building products in terms of their fire response characteristics, as a replacement for the various classification systems in existence in individual European countries [Wickström & Göransson, 1987, 1992].

The Lund model also predicts a number of room fire parameters of wall linings, with the same objective as the Eurefic model, and originated at Lund University (Sweden) [Karlsson & Magnusson, 1991, 1992]. It differs from the Eurefic model in a number of ways. First, it uses input from the lateral ignition and spread of flame apparatus (LIFT, ASTM E 1321, *Standard Test Method for Determining Material Ignition and Flame Spread Properties*) as well as from the cone calorimeter (ASTM E 1354 or ISO 5660), while the Eurefic model uses cone data only. Second, it predicts a large number of room fire test variables in addition to heat release rate and time to flashover. Third, this fire model, while based on the same room-corner test for wall linings (ISO 9705), uses a scenario with material on the walls only, rather than on the walls and ceiling. Finally, this model is based on a fundamental, rather than an empirical, approach. The model assumes that the total heat release rate comes from the following five sources:

(a) The gas burner;

(b) The vertical wall area behind the burner flame;

(c) A horizontal strip of material at the ceiling/wall intersection corresponding to the vertical height of the ceiling jet;

(d) The wall material in the upper layer, after flame spread has started; and

(e) The wall linings burning below the hot gas layer.

The model has limited direct applicability, because the test is rarely conducted under the necessary conditions. Nevertheless, the Lund model has greater potential than the Eurefic model, because its fire scenario can be altered with greater flexibility.

The Cleary-Quintiere model provides for the development of a set of equations that predicts different full-scale fire parameters, primarily those associated with flame spread, based on input data from the lateral ignition and flame spread test (ASTM E 1321, LIFT) and cone calorimeter (ASTM E 1354) heat release rate test methods [Cleary & Quintiere, 1991]. The main fire properties necessary for input include:

(a) The average peak heat release rate per unit area at a certain incident heat flux in the cone calorimeter (in kW/m^2);

(b) The burn time in the cone calorimeter at the same incident heat flux (i.e., the time during which a significant amount of heat is released), in (a);

(c) The time to ignition, T_{ig}, in the cone calorimeter or the LIFT apparatus at an incident heat flux corresponding to the minimum flux for wind-aided flame spread (in sec);

(d) The flame heating parameter for opposed flame spread, from the LIFT apparatus (Φ, in sec kW^2/m^3); and

(e) The minimum temperature for opposed flow flame spread (also from the LIFT) in °C. The data can be used to predict time to flashover or to peak heat release rates as well as actual peak heat release rates. The model is flexible enough that it can be applied to both the ISO 9705 and NFPA 265, *Standard Methods of Fire Tests for Evaluating Room Fire Growth Contribution of Textile Wall Coverings*. The input parameters are partially empirical.

An extension of the Cleary-Quintiere model also exists that includes the added effect of thermal feedback due to the increase of temperature within the room [Quintiere, 1993]. It has been applied to predict ISO 9705 wall lining material data and is in the process of being applied to predict NFPA 265 data. Its reliability is still unknown.

A number of other room fire models have been proposed and have been discussed recently [Janssens, 1992b].

A-6-6.4 Fire performance of floor finish items is often assessed by determining the critical radiant flux in the flooring radiant panel (NFPA 253, *Standard Method of Test for Critical Radiant Flux of Floor Covering Systems Using a Radiant Heat Energy Source*, or ASTM E 648, *Standard Test Method for Critical Radiant Flux of Floor-Covering Systems Using a Radiant Heat Energy Source*). However, the results of this test are not suitable for use in the calculations cited in this document [Briggs et al., 1992; Lawson, 1993; Tomann, 1993].

A-6-8.1 The use of a "backyard test" can be a useful screening method for prediction of the heat release rate of upholstered furniture. In this test, an actual piece of furniture (or a full-scale mock-up) is exposed to the same ignition source as that in ASTM E 1537, *Standard Test Method for Fire Testing of Real Scale Upholstered Furniture Items*, in a relatively draft-free environment. Visual observations of the results are made, but no heat release measurements are made. This setup allows reasonable predictions of some heat release rate results in the actual instrumented fire tests. It does not provide any estimation of total heat release. Figure A-6-8.1(a) represents results where chairs were divided into those that produce peak rates of heat release of under 40 kW and over 300 kW. Of fourteen systems tested and deemed to give off low heat release rates, none actually exceeded peak values of 250 kW, and four exceeded 80 kW. Of six systems tested and deemed to give off high heat release rate, none gave off peak values lower than 80 kW, and three gave off values between 100 kW and 250 kW. The actual experiments for which results are represented in Figure A-6-8.1(a) were all carried out with balanced, woven fabrics of different types but with the same foam and interliner barrier. A number of other individual experiments were made with other materials, and the reliability of the results was much less satisfactory. However, this work indicates the clear value of visual observation conducted by those who are experienced.

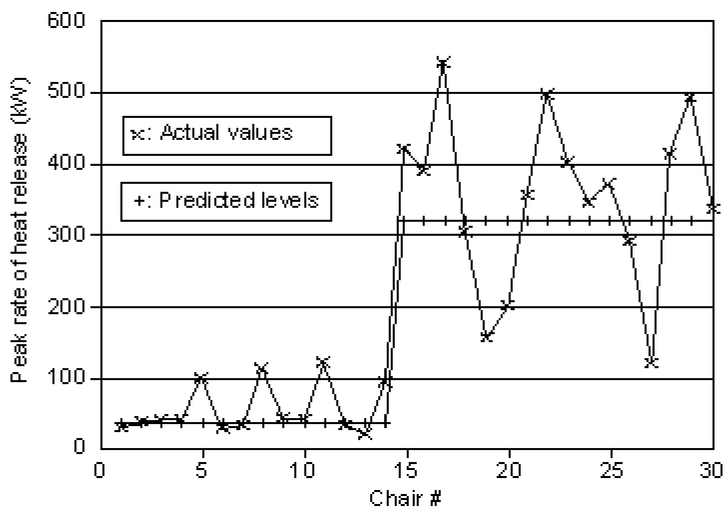


Figure A-6-8.1(a) Predictions of the results of full-scale ASTM E 1537 tests with upholstered furniture items (backyard test) and actual observed values.

An attempt also has been made to predict peak heat release rate values based on fabric weight. It has been shown that fabric weight alone might not be a reliable indicator of furniture heat release rate. In this case, a number of tests were carried out using a single specific fabric/interliner/foam/chair construction system. The only variable was the weight of the fabric. In a follow-up series of tests, a different type of fabric was used. All the results are shown in Figure A-6-8.1(b), which indicates that a five-fold increase in fabric weight was not sufficient, in this particular case, to differentiate significantly among the fire performance of the chairs. In one series, a definite trend towards increased heat release with increased fabric weight was evident, even though the error bars overlapped. In the other case, all systems produced nondifferentiable results. This is somewhat surprising since other work has shown that, in some systems, the effect of the fabric is the dominant one on fire performance [Hirschler & Shakir, 1991].

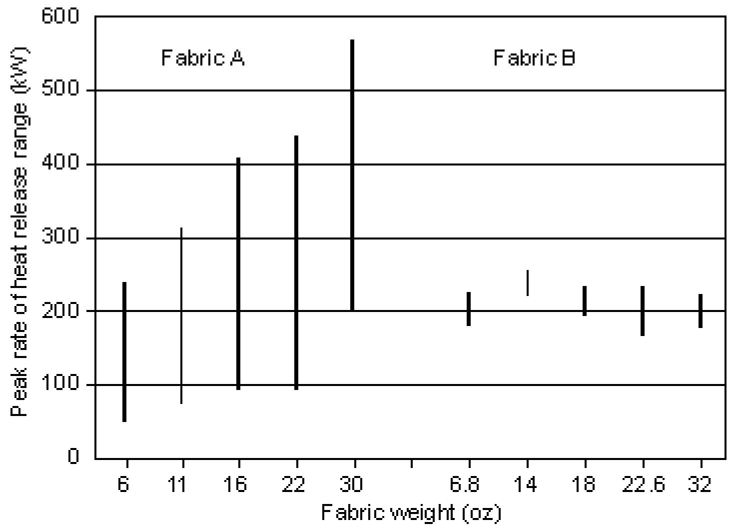


Figure A-6-8.1(b) Effect of fabric weight on heat release rate in full-scale ASTM E 1537 upholstered furniture tests using two fabrics, A and B.

Appendix B Referenced Publications

B-1 The following documents or portions thereof are referenced within this guide for informational purposes only and thus are not considered part of the recommendations of this document. The edition indicated for each reference is the current edition as of the date of the NFPA issuance of this document.

B-1.1 NFPA Publications. National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.

NFPA *101*, *Life Safety Code*, 1994 edition.

NFPA 253, *Standard Method of Test for Critical Radiant Flux of Floor Covering Systems Using a Radiant Heat Energy Source*, 1995 edition.

NFPA 255, *Standard Method of Test of Surface Burning Characteristics of Building Materials*, 1996 edition.

NFPA 265, *Standard Methods of Fire Tests for Evaluating Room Fire Growth Contribution of Textile Wall Coverings*, 1994 edition.

B-1.2 Other Publications.

B-1.2.1 ASTM Publications. American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103-1187.

ASTM E 84, *Standard Test Method for Surface Burning Characteristics of Building Materials*, 1995.

ASTM E 648, *Standard Test Method for Critical Radiant Flux of Floor-Covering Systems Using a Radiant Heat Energy Source*, 1994.

ASTM E 906, *Standard Test Method for Heat and Visible Smoke Release Rates for Materials and Products*, 1993.

ASTM E 1321, *Standard Test Method for Determining Material Ignition and Flame Spread Properties*, 1993.

ASTM E 1354, *Standard Test Method for Heat and Visible Smoke Release Rates for Materials and Products Using an Oxygen Consumption Calorimeter*, 1994.

ASTM E 1474, *Standard Test Method for Determining the Heat Release Rate of Upholstered Furniture and Mattress Components or Composites Using a Bench Scale Oxygen Consumption Calorimeter*, 1994.

ASTM E 1537, *Standard Test Method for Fire Testing of Real Scale Upholstered Furniture Items*, 1995.

B-1.2.2 ISO Publications. International Organization for Standardization, c/o American National Standards Institute, 11 West 42nd Street, 13th Floor, New York, NY 10036.

ISO 5660, *Fire Tests — Reaction to Fire — Part 1: Rate of Heat Release from Building Products (Cone Calorimeter Method)*, 1993.

ISO 9705, *Fire Tests — Full Scale Room Fire Tests for Surface Products*, 1991.

B-1.2.3 Bibliography.

Babrauskas, V., "Combustion of Mattresses Exposed to Flaming Ignition Sources, Part I, Full-Scale Tests and Hazard Analysis," National Bureau of Standards, Gaithersburg, MD, *NBSIR 77-1290*, (1977).

Babrauskas, V., "Estimating Room Flashover Potential," *Fire Technology*, 16, 94-103, 112 (1980), (1980a).

Babrauskas, V., "Full-Scale Burning Behavior of Upholstered Chairs," *NBS Tech. Note 1103*, National Bureau of Standards, Gaithersburg, MD, 1979.

Babrauskas, V., "Will the Second Item Ignite?," *Fire Safety Journal*, 4, 281-292 (1981-82).

Babrauskas, V., and Krasny, J., "Fire Behavior of Upholstered Furniture," *NBS Monograph 173*, National Bureau of Standards, Gaithersburg, MD, 1985.

Babrauskas, V., Lawson, J. R., Walton, W. D., and Twilley, W. H., "Upholstered Furniture Heat Release Rates Measured with a Furniture Calorimeter," National Bureau of Standards, Gaithersburg, MD, *NBSIR 82-2604*, December 1982.

Babrauskas, V., and Walton, W. D., "Simplified Characterization of Upholstered Furniture Heat Release Rates," *Fire Safety Journal*, 181-192 (1986).

Barile, P., "A Systematic Approach for Predicting Compliance with Technical Bulletin 133 for a Vast Combination of Chair Styles & Fabrics," *Proc. 18th Intern. Conf. Fire Safety*, Jan. 11-15, 1993, Millbrae, CA. Ed. Hilado, C.J., Product Safety Corp., Sunnyvale, CA, 20-31 (1993).

Belles, D. W., Fisher, F. L., and Williamson, R. B., "How Well Does the ASTM E-84 Predict Fire Performance of Textile Wall Coverings?," *Fire Journal*, 82 (1), 24-30, 74 (1988).

Briggs, P. J., Harris, S. R., Ollerenshaw, M., Van Hees, P., and Van Wesemael, E., "Full Scale Fire Testing of Carpets in Room/Corridor Scenarios and Comparisons with Small Scale Test Procedures," *Flame Retardants 1992*, Ed. The Plastics and Rubber Institute, Elsevier, London, UK, 297-307 (1992.

Budnick, E. K., "Mobile Home Living Room Fire Studies: The Role of Interior Finish," National Bureau of Standards, Gaithersburg, MD, *NBSIR 78-1530*, (1978).

Budnick, E. K., and Klein, D. P., "Mobile Home Fire Studies: Summary and Recommendations," National Bureau of Standards, Gaithersburg, MD, *NBSIR 79-1720*, (1979).

Budnick, E. K., Klein, D. P., and O'Laughlin, R. J., "Mobile Home Bedroom Fire Studies: The Role of Interior Finish," National Bureau of Standards, Gaithersburg, MD, *NBSIR 78-1531*, (1978).

Cleary, T. G., and Quintiere, J. G., "A Framework for Utilizing Fire Property Tests, in Fire Safety Science," *Fire Safety Science, Proc. Third Int. Symp.*, Eds. G. Cox and B. Langford, Elsevier, London, UK, 647-56 (1991).

Damant, G. H., McCormack, J. A., Mikami, J. F., and Wortman, P. S., "The California Technical Bulletin 133 Test: Some Background and Experience," *Proc. 14th Intern. Conf. Fire Safety*, Jan. 9-13, 1989, Millbrae, CA. Ed. Hilado, C. J., Product Safety Corp., Sunnyvale, CA, 1-12 (1989).

Damant, G. H., and Nurbakhsh, S., "Heat Release Rates of Seating Furniture Using California Technical Bulletin 133," *Heat Release & Fire Hazard, 1st U.S. Symposium*, *Abstracts*, December 1991, San Diego, CA, InterScience Communications, London, UK, 15-17 (1991).

Dietenberger, M. A., "Upholstered Furniture: Detailed Model," Chapter 14, *Heat Release in Fires*, Elsevier, London, UK, Eds. V. Babrauskas and S. J. Grayson, 479-518 (1992).

Fang, J. B., "Fire Buildup in a Room and the Role of Interior Finish Materials," National Bureau of Standards, Gaithersburg, MD, *NBS Technical Note 879*, (1975).

Fang, J. B., and Breese, J. N., "Fire Development in Residential Basement Rooms," National Bureau of Standards, Gaithersburg, MD, *NBSIR 80-2120*, (1980).

Gallagher, J. A., "Minimum Flux for Fire Propagation: A New Parameter for Classification of Foam/Fabric Composites," *J. Fire Sci.*, 10, 40-57 (1992).

Grand, A. F., Priest, D. N., and Stansberry, H. W., "Burning Characteristics of Upholstered Chairs," in *Fire and Flammability of Furnishings and Contents of Buildings*, ASTM STP 1233. Ed. Fowell, A. J., Amer. Soc. of Testing and Materials, Philadelphia, PA, 63-82 (1994).

Hågglund, B., Janson, R., and Onnermark, B., "Fire Development in Residential Rooms After Ignition from Nuclear Explosions," FOA C20016-DG (A3), Forsvarets Forskningsanstalt, Stockholm, Sweden, 1974.

Harmathy, T. Z., "A New Look at Compartment Fires, Part I," *Fire Technology*, 8, 3, 196-217 (1972), (1972a).

Harmathy, T. Z., "A New Look at Compartment Fires, Part II," *Fire Technology*, 8, 4, 326-351 (1972), (1972b).

Heselden, A. J. M., "Results of an International Cooperative Program on Fully-Developed Fires in Single Compartments. Fire-Resistive Requirements for Buildings — A New Approach," Symposium No. 5, 2-13, *Proc. of the Joint Fire Research Organization*, London, UK, September 28, 1971, 1973.

Hirschler, M. M., "Fire Tests and Interior Furnishings," *Fire and Flammability of Furnishings and Contents of Buildings*, ASTM STP 1233, Ed. Fowell A. J., Amer. Soc. of Testing and Materials, Philadelphia, PA, 7-31 (1994).

Hirschler, M. M., and Shakir, S., "Comparison of the Fire Performance of Various Upholstered Furniture Composite Combinations (Fabric/Foam) in Two Rate of Heat Release Calorimeters: Cone and Ohio State University Instruments," *J. Fire Sci.*, 9, 222-248 (1991).

Hirschler, M. M., and Smith, G. F., "Flammability of Sets of Fabric/Foam Combinations for Use in Upholstered Furniture," *Fire Safety Journal*, 16, 13-31 (1990).

Janssens, M., "Determining Flame Spread Properties from Cone Calorimeter Measurements: General Concepts," Chapter 9a, *Heat Release in Fires*, Elsevier, London, UK, Eds. V. Babrauskas and S. J. Grayson, 265-81 (1992), (1992a).

Janssens, M., "Room Fire Models, General," Chapter 6a, *Heat Release in Fires*, Elsevier, London, UK, Eds. V. Babrauskas and S. J. Grayson, 113-158 (1992), (1992b).

Jones, W. W., and Peacock, R. D., "Technical Reference Guide for FAST," Version 18, National Institute of Standards Technology, *NIST Technical Note 1262*, Gaithersburg, MD, May 1989.

Karlsson, B., and Magnusson, S. E., "Combustible Wall Lining Materials: Numerical Simulation of Room Fire Growth and the Outline of a Reliability Based Classification Procedure," *Fire Safety Science, Proc. Third Int. Symp.*, Eds. G. Cox and B. Langford, Elsevier, London, UK, 667-76 (1991).

Karlsson, B., and Magnusson, S. E., "An Example Room Fire Model," Chapter 6b, *Heat Release in Fires*, UK, Eds. V. Babrauskas and S. J. Grayson, Elsevier, London, 159-172 (1992)

Klein, D. P., "Characteristics of Incidental Fires in the Living Room of a Mobile Home," National Bureau of Standards, Gaithersburg, MD, *NBSIR 78-1522*, (1978).

Lawson, J. R., "Fire Tests and Flooring Materials," *Proc. 2nd. Int. Conf. on Fire and Materials*, Sept. 23-24, 1993, Crystal City, VA, InterScience Communications, London, UK, 253-62 (1993).

Lee, B. T., and Breese, J. N., "Submarine Compartment Fire Study — Fire Performance Evaluation of Hull Insulation," National Bureau of Standards, Gaithersburg, MD, *NBSIR 78-1584*, (1979).

McCaffrey, B. J., and Rockett, J. A., Natl Bur. Standards, Gaithersburg, MD, *J. Res.*, 82, 2, 107-117 (1977).

McCaffrey, B. J., Quintiere, J. G., and Harkleroad, M. F., "Estimating Room Temperatures and the Likelihood of Flashover Using Fire Data Correlations," *Fire Technology*, 17, 2, 98-119 (1981).

Pape, R., and Waterman, T., "Program Documentation and User's Guide (Addendum) Semistochastic Approach to Predicting the Development of a Fire in a Room from Ignition to Flashover — RFIRES," contract to National Bureau of Standards, Gaithersburg, MD, NBSGCR 77-112 (1976).

Parker, W. J., and Lee, B. T., "Fire Build-up in Reduced Size Enclosures. In: Fire Safety Research," *Proc. of a Symposium Held at the National Bureau of Standards, Gaithersburg, MD on August 22, 1973*. Eds. M. J. Butler and J. A. Slater, National Bureau of Standards, Gaithersburg, MD, NBS SP-411, 139-53 (1974).

Parker, W. J., Tu, K. M., Nurbakhsh, S., and Damant, G. H., "Furniture Flammability: an Investigation of the California Technical Bulletin 133 Test. Part III: Full Scale Chair Burns," *NISTIR 90-4375*, National Institute of Standards Technology, Gaithersburg, MD, 1990.

Quintiere, J. G., "A Simulation Model for Fire Growth on Materials Subject to a Room-Corner Test," *Fire Safety J.*, 20, 313-39 (1993).

Quintiere, J. G., "Smoke Measurements: An Assessment of Correlation Between Laboratory and Full-Scale Experiments," *Fire and Materials*, 6, 145-60 (1982).

Quintiere, J. G., and Harkleroad, M. T., "New Concepts for Measuring Flame Spread Properties," *Fire Safety: Science and Engineering,* ASTM STP 882, Ed. T. Z. Harmathy, American Society for Testing and Materials, Philadelphia, PA, 239-269 (1985).

Quintiere, J. G., and McCaffrey, B. J., "The Burning of Wood and Plastic Cribs in an Enclosure: Volume I," National Bureau of Standards, Gaithersburg, MD, *NBSIR 80-2054* (1980).

Schuhmann, J. G., and Hartzell, G. E., "Flaming Combustion Characteristics of Upholstered Furniture," *J. Fire Sci.*, 7, 368-402 (1989).

Smiecinski, T. M., Grace, O. M., and Wujcik, S. E., "Performance of Foam and Fabric Composites in Large-Scale Furniture Flammability Tests," *Proc. 14th Intern. Conf. Fire Safety*, Jan. 9-13, 1989, Millbrae, CA. Ed. C. J. Hilado, Product Safety Corp., Sunnyvale, CA, 35-40 (1989).

Smith, E. E., "Measuring Rate of Heat, Smoke and Toxic Gas Release," *Fire Technology*, 237-45 (1972).

Smith, E. E., "Release Rate Tests and Their Application," *J. Fire and Flammability,* 8, 309-323 (1977).

Smith, E. E., "Predicting Fire Performance Using Release Rate Information," *Proc. 4th. Int. Conf. Fire Safety*, San Francisco, CA. Ed. C. J. Hilado, 229-43 (1978).

Smith, E. E., and Satija, S., "Release Rate Model for Developing Fires," *J. Heat Transfer*, 105, 282-87 (1983).

Smith, W. K., Naval Weapons Center, China Lake (unpublished reports).

Thomas, P. H., and Heselden, A. J. M., "Fully-Developed Fires in Single Compartments," A Cooperative Research Program of the CIB, *Fire Research Note No. 923*, Fire Research Station, Borehamwood, UK, (1972).

Thomas, P. H., "Testing Products and Materials for Their Contribution to Flashover in Rooms," *Fire and Materials,* 5, 103-11 (1981).

Tomann, J., "Comparison of Nordtest Fire 007, CEN Draft Proposal (Radiant Panel) and Cone Calorimeter Methods in the Fire Testing of Floor Coverings," *Fire and Materials,* 17, 185-90 (1993).

Villa, K. M., and Babrauskas, V., "Cone Calorimeter Rate of Heat Release Measurements for Upholstered Composites of Polyurethane Foam," National Institute of Standards Technology, Gaithersburg, MD, *NISTIR 4652*, August 1991.

Wickström, U., and Göransson, U., "Prediction of Heat Release Rates of Large Scale Room Fire Tests Based on Cone Calorimeter Results," *J. Testing and Evaluation,* 15, 364-370 (1987).

Wickström, U., and Göransson, U., Full-Scale/Bench-Scale Correlations of Wall and Ceiling Linings, Chapter 13, *Heat Release in Fires*, Eds. V. Babrauskas and S. J. Grayson, Elsevier, London, UK, 461-77 (1992).

NFPA 560

1995 Edition

Standard for the Storage, Handling, and Use of Ethylene Oxide

for Sterilization and Fumigation

1995 Edition

This edition of NFPA 560, *Standard for the Storage, Handling, and Use of Ethylene Oxide for Sterilization and Fumigation*, was prepared by the Technical Committee on Industrial and Medical Gases and acted on by the National Fire Protection Association, Inc., at its Annual Meeting held May 22-25, 1995, in Denver, CO. It was issued by the Standards Council on July 21, 1995, with an effective date of August 11, 1995.

This edition of NFPA 560 was approved as an American National Standard on August 11, 1995.

Origin and Development of NFPA 560

In June, 1990 a request was made by a manufacturer of ethylene oxide to develop a new standard for the storage, handling, and use of ethylene oxide for sterilization and fumigation. This request addressed the replacement of the nonflammable mixture of ethylene oxide and freon with pure ethylene oxide, which was occurring concurrent with the reduced use of freon for environmental reasons. The request was reviewed by the NFPA Standards Council, which published a notice in the August, 1990 edition of *Fire News* asking for public input on the recommendation.

At its January, 1991 meeting, the NFPA Standards Council approved the request and the development of the standard was assigned to the NFPA Technical Committee on Industrial and Medical Gases (IMGAS). The IMGAS Committee established a task force on ethylene oxide, which developed a draft standard that was made available for public review and notice of its availability was published in the December 1993/January 1994 edition of *Fire News* with a public proposal closing date of January 21, 1994. The IMGAS Committee reviewed the proposals and the Committee's report was published in the 1995 Annual Meeting Report on

Proposals. Further revisions were published in the 1995 Annual Meeting Report on Comments.

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Alternates

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(Alt. to L. Wolpert)

Jason J. Raasch, Underwriters Laboratories, IL

Committee Scope: This Committee shall have primary responsibility for documents on the storage, transfer, and use of industrial gases. Included are the storage and handling of such gases in their gaseous or liquid phases; the installation of associated storage, piping, and distribution equipment; and operating practices. The Committee also has a technical responsibility for contributions in the same areas for medical gases and clean rooms.

NFPA 560
Standard for the
Storage, Handling, and Use of
Ethylene Oxide for Sterilization and Fumigation

1995 Edition

NOTICE: An asterisk (*) following the number or letter designating a paragraph indicates explanatory material on that paragraph in Appendix A.
Information on referenced publications can be found in Chapter 13 and Appendix C.

Chapter 1 General

1-1 Scope.

This standard shall apply to the storage and handling of ethylene oxide in portable containers for its use in sterilization and fumigation. It also shall apply to flammable mixtures of ethylene oxide with other chemicals.

This standard shall not apply to:

(a) Nonflammable mixtures of ethylene oxide with other chemicals.

(b) Ethylene oxide manufacturing facilities, and container filling, refilling, or transfilling facilities.

(c) The off-site transportation of portable containers of ethylene oxide.

NOTE: For regulations on the transportation of gases, see *Code of Federal Regulations*, 49 CFR Parts 100 through 179 (*Transportation*), and Transportation of Dangerous Goods Regulations of Transport Canada.

(d) Facilities using ethylene oxide as a chemical feed stock.

(e) Ethylene oxide in chambers 10 ft^3 (0.283 m^3) or less in volume, or for containers holding 200 g (7.05 oz) of ethylene oxide or less.

1-2 Alternate Materials, Equipment, and Procedures.

The provisions of this standard are not intended to prevent the use of any material, method of construction, or installation procedure not specifically prescribed by this standard, provided any such alternate is acceptable to the authority having jurisdiction (*see Section 1-4, Definitions*). The authority having jurisdiction shall require that sufficient evidence be submitted to substantiate any claims made regarding the safety of such alternates.

1-3 Retroactivity.

Unless otherwise stated, the provisions of this standard shall not be applied retroactively to existing systems that were in compliance with the provisions of the standard in effect at the time of installation.

1-4 Definitions.

Aeration Room. A room or area with controlled temperature or airflow where ethylene oxide sterilized products are held initially for offgassing.

Atmospheric Vents. All points where pipes, stacks, or ducts are open to the atmosphere including discharge points from emissions control devices, vent pipes from safety valves, vent pipes from filters or pumps, and other vents.

Authority Having Jurisdiction. The organization, office, or individual responsible for approving equipment, an installation, or a procedure.

NOTE: The phrase “authority having jurisdiction” is used in NFPA documents in a broad manner, since jurisdictions and approval agencies vary, as do their responsibilities. Where public safety is primary, the authority having jurisdiction may be a federal, state, local, or other regional department or individual such as a fire chief; fire marshal; chief of a fire prevention bureau, labor department, or health department; building official; electrical inspector; or others having statutory authority. For insurance purposes, an insurance inspection department, rating bureau, or other insurance company representative may be the authority having jurisdiction. In many circumstances, the property owner or his or her designated agent assumes the role of the authority having jurisdiction; at government installations, the commanding officer or departmental official may be the authority having jurisdiction.

Chime Ring. The two raised rings circling the outer shell of DOT 5P (1A1) ethylene oxide drums. These rings protect the drum but are not intended for lifting purposes.

Container. For the purposes of this standard, a cylinder, drum, or other pressure vessel built to DOT, ASME, or other pressure vessel code and used to transport or store ethylene oxide.

Cylinder. A portable compressed gas container, fabricated to or authorized for use by the U.S. Department of Transportation (DOT), or fabricated to Transport Canada (TC) or the ASME *Boiler and Pressure Vessel Code*, Section VIII, *Rules for the Construction of Unfired Pressure Vessels*.

Drum. For the purposes of this standard, containers built to DOT specification 5P (1A1).

Labeled. Equipment or materials to which has been attached a label, symbol, or other identifying mark of an organization that is acceptable to the authority having jurisdiction and concerned with product evaluation that maintains periodic inspection of production of labeled equipment or materials and by whose labeling the manufacturer indicates compliance with appropriate standards or performance in a specified manner.

Limited-Combustible Material. A material (as defined in NFPA 220, *Standard on Types of Building Construction*) not complying with the definition of noncombustible material which, in the form in which it is used, has a potential heat value not exceeding 3500 Btu per lb (8141 kJ/kg), and complies with one of the following paragraphs (a) or (b). Materials subject to increase in combustibility or flame spread rating beyond the limits herein established through the effects of age, moisture, or other atmospheric condition shall be considered combustible.

(a) Materials having a structural base of noncombustible material, with a surfacing not exceeding a thickness of $^1/_8$ in. (3.2 mm), which has a flame spread rating not greater than 50.

(b) Materials, in the form and thickness used, other than as described in (a), having neither a flame spread rating greater than 25 nor evidence of continued progressive combustion and of such composition that surfaces that would be exposed by cutting through the material on any plane would have neither a flame spread rating greater than 25 nor evidence of continued progressive combustion. (*See NFPA 259, Standard Test Method for Potential Heat of Building Materials.*)

Listed. Equipment or materials included in a list published by an organization acceptable to the authority having jurisdiction and concerned with product evaluation that maintains periodic inspection of production of listed equipment or materials and whose listing states either that the equipment or material meets appropriate standards or has been tested and found suitable for use in a specified manner.

NOTE: The means for identifying listed equipment may vary for each organization concerned with product evaluation, some of which do not recognize equipment as listed unless it is also labeled. The authority having jurisdiction should utilize the system employed by the listing organization to identify a listed product.

Outgassing. Release of adsorbed and absorbed ethylene oxide after sterilization.

Pressure Relief Device. A spring-operated pressure relief valve or rupture disc.

Shall. Indicates a mandatory requirement.

Should. Indicates a recommendation or that which is advised but not required.

Special Buildings. For the purposes of this standard, a building used exclusively for the ethylene oxide sterilization process.

Special Room. A separate enclosed area that is part of or attached to a building and is used exclusively for the ethylene oxide sterilization process.

Storage. An inventory of compressed or liquefied gases in containers that are not in the process of being examined, serviced, refilled, loaded, or unloaded.

Chapter 2 Receiving and Unloading Ethylene Oxide Containers

2-1 Scope.

This chapter applies to the handling of both full and empty ethylene oxide containers at a facility, including:

(a) Handling of the containers between the truck and the dock,

(b) Container inspection at the dock,

(c) Handling of the containers within the facility.

2-2 Procedures.

2-2.1

Drums shall not be lifted by placing the forks under the chime rings on the drums.

2-2.2

Prior to the unloading of ethylene oxide containers, the vehicle engine shall be turned off, the brakes set, and the wheels chocked.

2-2.3

Smoking or open flames shall not be permitted within 20 ft (6.1 m) of any area where ethylene oxide containers are handled.

2-2.4

Ethylene oxide cylinders shall be secured to hand trucks or lift trucks during movement.

2-2.5

Ethylene oxide containers shall be kept upright at all times. Containers shall not be stacked or rolled.

2-2.6

Immediately after off-loading, ethylene oxide containers shall be inspected and the following checks shall be performed:

(a) An examination for evidence of damage to the container or valves,

(b) A confirmation that the valves are equipped with valve outlet plugs or caps,

(c) An inspection of the container labeling to confirm that each container is labeled ethylene oxide,

(d)* A leak test of the container including valves and fuse plugs.

Ethylene oxide containers shall not be moved to storage until the inspection is complete.

2-2.7

In the event that any container fails incoming inspection, the ethylene oxide supplier shall be notified. If a leaking container is found, the facility procedures for handling ethylene oxide leaks and spills shall be followed.

2-2.8

Ethylene oxide containers shall not be stored in the receiving area.

Exception: Areas dedicated to the receiving and storage of ethylene oxide only.

Chapter 3 Storage of Ethylene Oxide

3-1 General.

3-1.1

Storage areas shall be secured against unauthorized entry.

3-1.2

Storage of ethylene oxide in combination with other compressed or liquefied gases shall be in accordance with NFPA 55, *Standard for the Storage, Use, and Handling of Compressed and Liquefied Gases in Portable Cylinders*.

3-1.3

Ethylene oxide containers shall be kept upright at all times. Containers shall not be stacked.

3-2 Indoor Storage.

3-2.1 Storage Within Buildings.

Storage within buildings shall not be permitted except in special buildings and special rooms. (*See Chapter 11*.)

Exception: One cylinder containing up to 400 lb (181 kg) of ethylene oxide shall be permitted to be stored in a production area where required for production within eight hr.

3-2.2 Storage Within Special Buildings or Special Rooms.

3-2.2.1* The maximum quantity of ethylene oxide stored in a special building or special room shall be 10,000 lb (4540 kg).

3-2.2.2 The construction of all such special buildings, and rooms within, or attached to, other buildings, shall comply with Chapter 11.

3-2.2.3 Special buildings or rooms shall be classified for purposes of ignition source control in accordance with 7-1.1.

3-2.2.4 Heated indoor storage areas shall be arranged so that stored cylinders or other containers cannot be spot-heated or heated above 125°F (51.7°C).

3-3 Storage Outside of Buildings.

3-3.1 Location of Storage Outside of Buildings.

Storage outside of buildings shall be located in accordance with Table 3-3.1.

Table 3-3.1 Outdoor Storage of Ethylene Oxide
Minimum Horizontal Distance to:

Quantity of EO Stored [lb (kg)]	Nearest important building or group of buildings or line of adjoining property that can be built upon.	Busy thoroughfares or sidewalks, line of adjoining property occupied by schools, churches, hospitals, athletic fields, or other
800 (363 kg) or less	0	0
801 (363 kg) to 2400 (1089 kg)	0	10 ft (3 m)
2,401 (1089 kg) to 6,000 (2722 kg)	10 ft (3 m)	10 ft (3 m)
6,001 (2722 kg) to 10,000 (4536 kg)	20 ft (6 m)	20 ft (6 m)
Over 10,000 (4536 kg)	25 ft (7.6 m)	25 ft (7.6 m)

3-3.2 Requirements for Outdoor Storage Areas.

Outdoor storage areas shall have a minimum of 25 percent of the perimeter open to the atmosphere. This open space shall be permitted to incorporate chain link fence, lattice construction, open block, or similar materials for the full height and width of the opening.

(a) Storage areas shall be kept clear of dry vegetation and combustible materials for a minimum distance of 15 ft (4.6 m).

(b) Cylinders stored outside shall not be placed on the ground (earth) or on surfaces where water can accumulate.

(c) Storage areas shall be provided with physical protection from vehicle damage.

(d)* Storage areas shall be permitted to be covered with canopies of noncombustible construction.

Chapter 4 Piping Systems

4-1 Scope.

This chapter shall apply to ethylene oxide piping systems including pipe, tubing, flanges, gaskets, valves, fittings, flexible connectors, and the pressure containing parts of other components such as expansion joints and strainers, and devices used to mix, separate, distribute, meter, and control the flow of ethylene oxide. This chapter shall not apply to scrubber and vent systems.

4-2 Materials for Piping, Valves, and Fittings.

4-2.1 Materials.

All metallic materials used shall be specified in ASME B31.3, *Chemical Plant and Petroleum Refinery Piping*. The requirements of the hazardous materials section shall apply. The following restrictions shall also apply:

(a) All metallic materials used shall have a minimum melting point of greater than 1500°F (815.6°C).

(b) No furnace butt-welded steel product shall be used.

4-2.2* Joining Methods.

Joints shall be made gas-tight and shall be either welded, flanged, brazed, or threaded. Joints shall be welded when located in concealed spaces within buildings. The following shall also apply:

(a) *Welding.* All welding processes and procedures shall be in conformance with the ASME *Boiler and Pressure Vessel Code,* Section IX . The Oxy-Fuel Gas Welding (OFW) procedure shall not be used on any component or system fabricated to this standard.

(b) *Brazing.* All brazing processes and procedures shall be in strict conformance with the ASME *Boiler and Pressure Vessel Code,* Section IX . All braze alloys shall have a minimum melting point of 1000°F (537.8°C). The failure of the braze joint in the event of a fire exposure shall not in any way result in the release of additional fuel that can accelerate or spread the existing fire.

(c) *Soldering.* Soldering shall not be used for pressure containment or structural purposes. Soldering for hermetic/environmental sealing purposes as part of a mechanical sealing system shall be permitted. The failure of any soldering application in the event of a fire shall not allow a release of fuel that can accelerate or spread the existing fire.

(d) *Threading.* Threaded joints shall be made with a thread sealant or lubricant compatible with ethylene oxide.

4-3* Preparation for Dismantling of Piping.

Any piping and valves that have been used to transport ethylene oxide to or from a sterilizer to the emission control or release point shall be drained and purged prior to dismantling. The piping shall be purged free of flammable concentrations of ethylene oxide prior to cutting or welding on the lines. The piping shall be inspected for evidence of polymer prior to cutting or welding. If found, all polymer shall be removed prior to cutting or welding.

NOTE: For information on safety in cutting and welding see NFPA 51B, *Standard for Fire Prevention in Use of Cutting and Welding Processes.*

4-4 Valves.

Valves shall be designed for a minimum operating pressure of 150 psi (1030 kPa). All material used, including valve seat discs, packing, seals, and diaphragms shall be in accordance with Section 4-2.

4-5 Testing.

Pressure piping systems shall be tested and demonstrated to be free of leakage at 150 percent of the maximum anticipated operating pressure, prior to use. Vacuum piping shall be tested at the lowest anticipated operating pressure.

NOTE: For information on testing of piping systems see ASME B31.3, *Chemical Plant and Petroleum Refinery Piping*.

4-6 Identification.

Ethylene oxide lines shall be identified.

NOTE: For information on identification of piping see ASME A13.1, *Scheme for the Identification of Piping Systems*.

Chapter 5 Gas Dispensing Areas

5-1 General.

In addition to the requirements in Chapter 3, Storage of Ethylene Oxide, the following shall apply to areas where ethylene oxide is dispensed from containers. Ethylene oxide storage shall be permitted in dispensing areas.

5-1.1

Indoor dispensing areas shall be equipped with a continuous gas detection system that provides an alarm when ethylene oxide levels exceed 25 percent of the lower limit of flammability (7,500 ppm).

NOTE: Additional detection at lower levels may be required to meet the requirements of the Occupational Safety and Health Administration of the U. S. Department of Labor (29 CFR 1910.1047).

5-1.2*

Exhaust ventilation shall be installed in all indoor dispensing areas used for ethylene oxide. Exhaust ventilation shall comply with the following:

(a) Mechanical ventilation shall be operated continuously at a rate of not less than 1 ft^3 per min per ft^2 (0.3 m^3 per min per m^2)of floor area of dispensing area.

(b) Exhaust ventilation shall not be recirculated within a room or building.

Exception: Where the air is treated to reduce the ethylene oxide concentration to below that which represents a hazard, recirculation shall be permitted. Controls shall be provided to ensure the performance of the treatment and recirculation system.

(c) The ventilation system shall be designed to prevent accumulation of ethylene oxide anywhere in the dispensing area.

(d) Loss of ventilation shall activate a visual and audible alarm and shall stop the flow of ethylene oxide at the remotely operated shutoff valve closest to the container.

5-2* Ethylene Oxide Containers.

5-2.1

No more than two ethylene oxide containers shall be connected to each sterilizer.

5-2.2

Before connections are made, containers shall be grounded.

5-2.3

The ethylene oxide supply line shall have a reverse flow prevention device to prevent contamination of the supply container where automatic switchover of containers is used.

5-2.4

Each ethylene oxide piping system from the containers to the process chamber shall have two remotely operated shutoff valves in the flow stream.

5-2.5

The valve required in 5-2.4 closest to the container shall be located 5 ft (1.5 m) or less from the container. The valves shall be operable from the sterilizer control room or other location outside the dispensing area.

5-2.6

Any supply piping containing liquid ethylene oxide that can be isolated shall be equipped with a pressure relief device.

5-3 Nitrogen System.

5-3.1

Nitrogen used for head space pressurization shall be no less than 99.9 percent nitrogen and shall contain no impurities that are chemically incompatible with ethylene oxide.

5-3.2

A reverse flow prevention device shall be provided to prevent ethylene oxide from entering the nitrogen supply system.

5-3.3

A particulate filter shall be provided to prevent rust from being introduced into an ethylene oxide container.

5-3.4

Refillable containers shall be pressurized with nitrogen to 50 psi (345 kPa) prior to disconnection and shipment to the supplier.

5-4 Vaporizer.

5-4.1

A valve shall be provided to control liquid flow to the vaporizer. This valve shall be permitted to be one of the valves required in 5-2.4.

5-4.2*

An indicating or recording device shall be provided at the control panel to demonstrate that ethylene oxide temperature is within the range of 60°F (16°C) to 200°F (93.3°C). An alarm shall be provided for out-of-range conditions.

5-5 Liquid Ethylene Oxide Piping.

Liquid ethylene oxide shall not be piped indoors beyond a special room.

Chapter 6 Operations

6-1 Operating Procedures Manual.

6-1.1

Each facility shall prepare and maintain an operating procedures manual covering facility startup, operation, and shutdown. These manuals shall include procedures for the safe operation of the facility under normal and nonroutine operation conditions. Manuals shall be accessible to facility operators at all times.

6-1.2

Operating procedures manuals shall include operator actions to be taken if toxic or flammable concentrations of ethylene oxide are detected in the facility.

6-1.3

Operating procedures shall include procedures for purging and inerting equipment and piping.

6-1.4

Operating procedures shall include procedures for addressing leakage and spills of ethylene oxide.

6-2* Sterilizer Operation.

6-2.1 Purging.

The vessel shall be purged to reduce the ethylene oxide concentration to less than 25 percent of the lower limit of flammability prior to opening the chamber door.

NOTE 1: Lower concentrations of ethylene oxide are required by OSHA (29 CFR 1910.1047) for personnel exposure.

NOTE 2: The use of nitrogen in enclosed spaces can pose an asphyxiation hazard.

6-2.2 Post-Cycle Ventilation.

A nonrecirculating ventilation system or equivalent means shall be provided to prevent ethylene oxide accumulation due to product outgassing prior to and during unloading of the sterilizer.

NOTE: Outgassing, depending on product characteristics, can be of sufficient magnitude to produce flammable mixtures of ethylene oxide.

6-2.3 Cycle Abort.

Ethylene oxide sterilizers shall be equipped with a manually initiated cycle abort feature accessible to the operator. This also shall be operable from outside the sterilizer area. A key-locked device shall not be permitted. The cycle abort operation shall remove flammable concentrations of ethylene oxide from the sterilizer.

6-3 Area Monitoring for Ethylene Oxide.

Ethylene oxide sterilizer areas shall be monitored continuously for ethylene oxide concentrations.

6-3.1

The gas detection system shall provide an audible and visual warning signal to indicate when concentrations of ethylene oxide reach a level of 25 percent of the lower limit of flammability of ethylene oxide.

6-3.2*

The gas detection system shall automatically shut off the supply at the ethylene oxide containers when the concentration of ethylene oxide exceeds 25 percent of the lower limit of flammability.

NOTE: Additional detection at lower levels may be required to meet the requirements of OSHA (*Code of Federal Regulations*, Title 29, Part 1910.1047).

6-4 Emergency Stop.

An emergency stop device shall be provided to halt all operating equipment including valves, rotating equipment, and heating apparatus on the sterilizer and gas dispensing equipment. The emergency stop shall be activated by a manually initiated feature accessible in the control room or at the control panel.

Chapter 7 Electrical Installation

7-1 Area Electrical Classification.

7-1.1

The sterilizer room, gas dispensing room, ethylene oxide container storage area, aeration rooms, and emission control area shall be classified as a Class I, Division 2, Group B area in accordance with NFPA 70, *National Electrical Code®*.

Exception: Aeration rooms shall be permitted to be unclassified electrically where it is demonstrated that flammable concentrations of ethylene oxide can not occur during all normal and nonroutine operating conditions, including power failure.

7-1.2

The interior of the sterilization vessel shall be classified Class I, Division 1, Group B.

7-2 Static Electricity Control.

All piping shall be bonded to an earth ground.

NOTE: For information on prevention of static electricity see NFPA 77, *Recommended Practice on Static Electricity*.

7-3 Grounding Requirements.

All equipment shall be grounded in accordance with NFPA 70, *National Electrical Code*, Article 250 and Section 501-16.

Chapter 8 Sterilizer Construction

8-1* Vessel.

Sterilizers operating at 15 psig (100 kPa) or higher shall be designed, built and stamped in accordance with the ASME *Boiler and Pressure Vessel Code*, Section VIII.

8-2 Rotating Equipment.

Rotating equipment exposed to flammable concentrations of ethylene oxide shall be designed to prevent sparking and localized overheating of surfaces during normal and nonroutine operation.

8-3 Pressure Relief Device.

A pressure relief device, set to open at the sterilizer's design pressure, shall be installed on each sterilizer. Pressure relief devices shall be inspected annually for corrosion or accumulation of material (such as polymer buildup) that could prevent operation.

8-3.1

The point of discharge of the pressure relief device shall not be located in an area where potential ignition sources exist or where ethylene oxide vapors could re-enter the building.

8-3.2

Shutoff valves shall not be installed in relief device discharge piping.

Chapter 9 Disposal and Emissions

9-1 Scope.

This chapter shall apply to the disposal and emission of ethylene oxide from sterilization facilities.

NOTE: The emphasis of this chapter is on those issues specifically related to fire safety. Sterilization facilities are required to comply with federal, state, and local environmental health and safety regulations.

9-2 Wet Scrubbers.

Where a wet scrubber is used, the following requirements shall apply:

(a) Wet scrubbing systems shall be designed so that scrubber solution cannot enter ethylene oxide vent or process lines.

(b) Sources of pure ethylene oxide liquid shall be prevented from being fed directly to scrubber systems designed only for ethylene oxide gas treatment.

9-3 Flare Stacks.

Where a flare stack is used, the following requirements shall apply:

(a) Flame arrestors shall be installed to prevent flame flashback into the sterilizer.

(b) Flare stack failure shall initiate a shutdown of the flare stack feed and an audible alarm.

9-4 Catalytic Converter.

Where a catalytic converter is used, it shall be designed to shut down or be bypassed if the temperature exceeds the maximum temperature determined by the catalyst supplier.

Chapter 10 Maintenance

10-1 General Requirements.

A written program shall be developed for the following maintenance activities:

(a) Confined space entry,

(b) Purging of equipment and piping,

(c) Welding (hot work) permit system,

(d) Lockout/tagout,

(e) Preventive maintenance for key equipment.

10-2 Maintenance Manuals.

Manuals shall be accessible to facility operators and maintenance personnel at all times.

Chapter 11 Construction

11-1 Scope.

This chapter covers the construction, ventilation, and heating of structures that house ethylene oxide storage, dispensing, and use. These structures shall be used exclusively for these purposes and for the housing of other materials having similar hazards, or they shall be permitted to be rooms attached to, or located within, buildings used for other purposes.

11-2 Separate Structures or Buildings.

11-2.1 Construction of Structures or Buildings.

11-2.1.1 Separate structures or buildings shall be one story in height and shall have walls, floors, ceilings, and roofs constructed of noncombustible or limited combustible materials. Exterior walls, ceilings, and roofs shall be constructed as follows:

(a) Of lightweight material designed for explosion venting, or

(b) If of heavy construction, such as solid brick masonry, concrete block, or reinforced concrete construction, explosion venting windows or panels in walls or roofs shall be provided.

NOTE: For information on venting of deflagrations, see NFPA 68, *Guide for Venting of Deflagrations.*

11-2.1.2 The floor of such structures or buildings shall not be located below ground level. Any space beneath the floor shall be of solid fill, or the perimeter of the space shall be entirely unenclosed.

11-2.2* Structure or Building Ventilation.

The structure or building shall be provided with general ventilation through the use of air supply inlets and exhaust outlets. These inlets and outlets shall be arranged to provide movement of well-mixed air throughout the space. Air circulation shall be at least 1.0 cfm per sq ft (0.3 m^3 per m^2) of floor area and shall be permitted to be provided by natural or mechanical means.

11-2.3 Structure or Building Heating.

Heating shall be by electrical appliances listed for Class I, Group B, Division 2 locations in accordance with NFPA 70, *National Electrical Code*, or shall be by means of steam or hot water radiation or other heating transfer medium with the heat source:

(a) Outside of the building, or

(b) In a separate room with a 2-hr fire resistance rating pressurized relative to the remainder of the building.

11-3 Special Rooms.

11-3.1 Construction of Special Rooms.

11-3.1.1 Special rooms attached to structures or special rooms located within structures shall have walls, floors, ceilings, and roofs constructed of noncombustible or limited-combustible materials.

11-3.1.2 The floor of a special room shall not be located below ground level. Any space beneath the floor shall be of solid fill, or the perimeter of the space shall be entirely unenclosed.

11-3.1.3 At least 25 percent of the room perimeter shall be an exterior wall designed as explosion venting.

Exception: Interior rooms shall be permitted in one-story buildings if the entire room roof is designed as explosion venting.

NOTE: For information on venting of deflagrations see NFPA 68, *Guide for Venting of Deflagrations*.

11-3.1.4 All interior walls shall have a fire resistance rating of at least 2 hr. Openings in interior walls shall be equipped with a minimum of 1-$^1/_2$-hr rated (B) fire doors.

NOTE: For information on fire doors, see NFPA 80, *Standard for Fire Doors and Fire Windows*.

11-3.1.5 All interior walls, and other walls of the room not designed as explosion venting, shall be designed to withstand an overpressure of at least 100 lb per ft^2 (4.8 kPa).

11-3.1.6 In multifloor buildings, where the space above the room ceiling is occupied or used, the ceiling shall be designed to withstand an uplift pressure of at least 100 lb per ft^2 (4.0 kPa).

11-3.2 Room Ventilation.

The room shall be provided with ventilation in accordance with 11-2.2.

11-3.3 Room Heating.

The room shall be provided with heating in accordance with 11-2.3.

Chapter 12 Fire Protection

12-1 Sprinklers.

All facilities storing or using ethylene oxide shall be protected by an automatic sprinkler system in accordance with NFPA 13, *Standard for the Installation of Sprinkler Systems*.

12-2 Ethylene Oxide Storage Areas.

Ethylene oxide storage areas shall be equipped with a deluge system in accordance with NFPA 16, *Standard on the Installation of Deluge Foam-Water Sprinkler and Foam-Water Spray Systems*.

Chapter 13 Referenced Publications

13-1

The following documents or portions thereof are referenced within this standard and shall be considered part of the requirements of this document. The edition indicated for each reference is the current edition as of the date of the NFPA issuance of this document.

13-1.1 NFPA Publications.

National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.

NFPA 13, *Standard for the Installation of Sprinkler Systems*, 1994 edition.

NFPA 16, *Standard on the Installation of Deluge Foam-Water Sprinkler and Foam-Water Spray Systems*, 1995 edition.

NFPA 55, *Standard for the Storage, Use, and Handling of Compressed and Liquefied Gases in Portable Cylinders*, 1993 edition.

NFPA 70, *National Electrical Code*, 1996 edition.

NFPA 220, *Standard on Types of Building Construction*, 1995 edition.

13-1.2 Other Publications.

13-1.2.1 ASME Publications. American Society for Mechanical Engineers, 345 East 47th St., New York, NY 10017.

ASME *Boiler and Pressure Vessel Code*, 1992 edition.

ASME B31.3–1993, *Chemical Plant and Petroleum Refinery Piping*.

Appendix A Explanatory Material

This Appendix is not a part of the requirements of this NFPA document but is included for informational purposes only.

A-2-2.6(d) Ethylene oxide containers should be tested for leakage prior to moving them inside a facility. Leak detection solutions can be used to test for leaks around valves and fuse plugs. This is often referred to as a soap test. Inexpensive hand-held leak detection instruments also are available.

A-3-2.2.1 Storage of over 5,000 lb (2268 kg) of ethylene oxide can also be covered by 29 CFR 1910.119 (OSHA). Hazard analyses are required by OSHA for facilities storing more than 5,000 lb (2268 kg) of ethylene oxide in one location. Hazard analyses are recommended for all facilities that store, use, and handle ethylene oxide. Refer to 29 CFR 1910.119, *Process Safety*

Management of Highly Hazardous Chemicals, for guidance on conducting such an analysis. The analysis should address the hazards of the operation, identification of any previous incidents, engineering and administrative controls to protect against hazards, consequences of the failure of engineering and administrative controls, facility site, and human factors, and qualitative evaluation of the range of possible effects on employee safety and health due to the failure of controls.

A-3-3.2(d) The rate of formation of ethylene oxide polymers increases as the temperature increases. Therefore, to minimize polymer formation, ethylene oxide containers should be sheltered from intense sunlight. Ethylene oxide containers should not be stored under plastic sheets. This can produce a greenhouse effect that results in release of the fusible plugs.

A-4-2.2

Welding is the preferred method of joining pipe. The use of welding is important in preventing leakage of ethylene oxide.

A-4-3

Cleaning the inside of lines used for ethylene oxide is necessary prior to opening the piping system to remove the combustible, oily ethylene oxide by-products (which also contain absorbed ethylene oxide), such as polymers or glycols. These by-products can build up gradually over time.

A-5-1.2

Local exhaust hoods are an effective means used to control ethylene oxide levels at the source of potential release.

A-5-2

Typical ethylene oxide drum hookup and piping are shown in Figures A-5-2 (a) and (b).

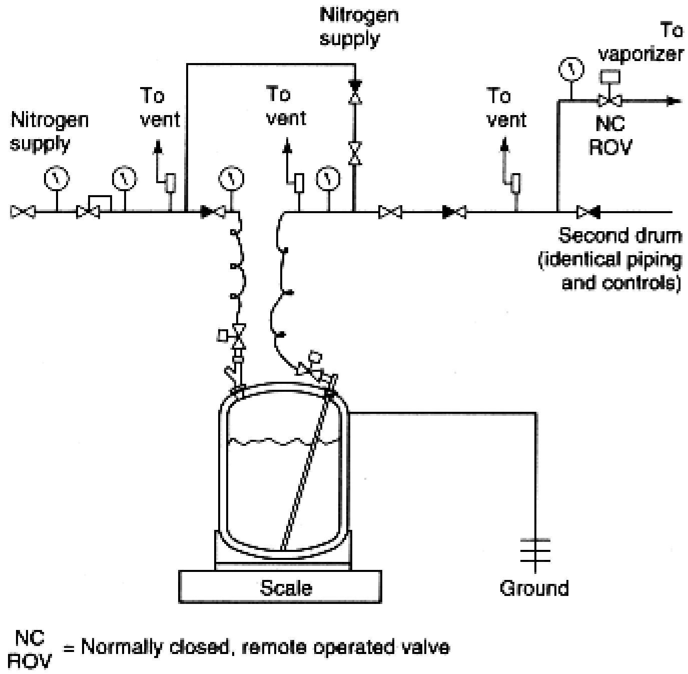


Figure A-5-2(a) Typical ethylene oxide drum hookup 1.

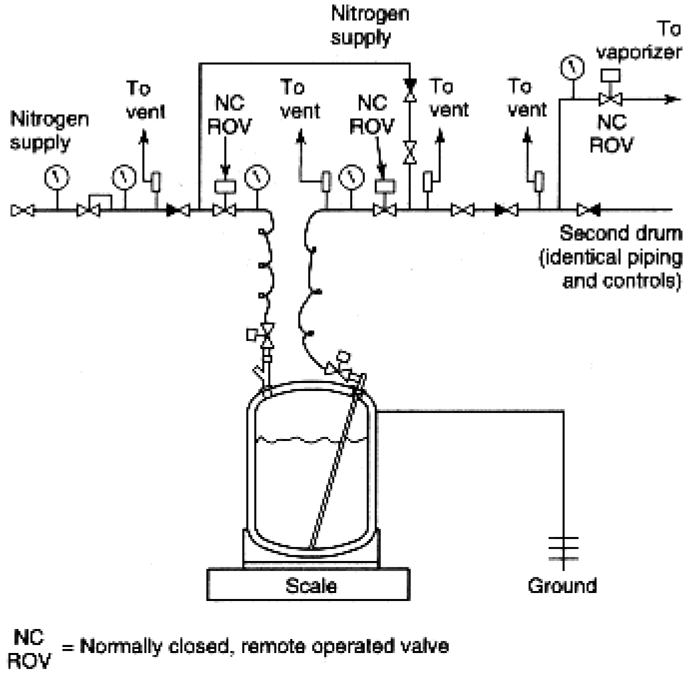


Figure A-5-2(b) Typical ethylene oxide drum hookup 2.

A-5-4.2

Monitoring of temperature in the ethylene oxide vapor stream provides a means to detect liquid ethylene oxide downstream of the vaporizer. The vaporizer should be equipped with a controller to maintain the desired temperature range for vaporization of ethylene oxide or ethylene oxide mixtures.

A-6-2 General.

Sterilization is performed in a closed vessel under controlled conditions of temperature, humidity, pressure, and ethylene oxide gas concentration. The process is a single-pass, batch operation where a number of steps are performed to complete the cycle. Process cycle parameters can vary widely to meet product sterilization requirements and can use flammable gas mixtures in the sterilizer.

A-6-3.2

Ethylene oxide gas supply shutoff is a minimum requirement; other operations such as emergency ventilation might also be appropriate.

A-8-1

Flame arrestors should be installed to prevent flame propagation from potential ignition sources external to the vessel. Locations for consideration are the vacuum pump suction line, air inbleed port, relief valve discharge, and other potential problem areas where flashbacks could occur.

A-11-2.2

In order to comply with this requirement and OSHA (29 CFR 1910.1047), specific local exhaust ventilation might be necessary in storage and dispensing areas, on the sterilizer, and in aeration rooms.

Appendix B Significant Properties of Ethylene Oxide

This Appendix is not a part of the requirements of this NFPA document but is included for informational purposes only.

B-1 Hazards of Ethylene Oxide

(Based on NFPA 49, *Hazardous Chemicals Data*).

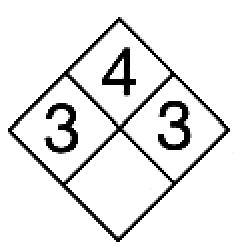
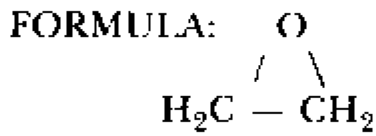


Figure B-1 Hazards of ethylene oxide.

SYNONYMS: di-methylene oxide; EO; EtO; 1,2-epoxyethane; oxirane

FORMULA:



DOT CLASS: Class 2.3, Poisonous gas

SHIPPING LABEL: POISON GAS and FLAMMABLE GAS

ID NO.: UN 1040

CAS NO.: 75-21-8

MOL. WT.: 44.0

STATEMENT OF HAZARDS: Flammable gas. Low ignition energy. Explosive decomposition may occur. Hazardous polymerization may occur. Serious health hazard.

EMERGENCY RESPONSE PERSONAL PROTECTIVE EQUIPMENT: Wear special protective clothing and positive pressure self-contained breathing apparatus.

SPILL OR LEAK PROCEDURES: Eliminate all ignition sources. Releases may require isolation or evacuation. Approach release from upwind. Stop or control the leak, if this can be done without undue risk. Use water spray to cool and disperse vapors, protect personnel, and dilute spills to form nonflammable mixtures. Water solutions no longer flammable in open areas when diluted as 1 part in 22 parts water. In enclosed areas such as sewers, dilution to 1 part in 100 parts water may be required to eliminate flash potential. Control runoff and isolate discharged material for proper disposal.

FIRE-FIGHTING PROCEDURES: Use flooding quantities of water as fog. Use water spray, dry chemical, “alcohol resistant” foam, or carbon dioxide. Use water spray to keep fire-exposed containers cool. Explosive decomposition may occur under fire conditions. Fight fire from protected location or maximum possible distance.

HEALTH HAZARDS: Serious health hazard. May be harmful if absorbed through skin or inhaled. Pulmonary edema may result. Irritating to skin, eyes, and respiratory system.

FIRE AND EXPLOSION HAZARDS: Flammable gas. Volatile flammable liquid below room temperature. Explosive decomposition may occur in vapor or liquid phases. Vapor forms explosive mixtures with air over a wide range. Vapors are heavier than air and may travel to a source of ignition and flash back. Closed containers may rupture violently when heated.

FLASH POINT: 4°F (–20°C)

AUTOIGNITION TEMPERATURE: 804°F (429°C) [AIT in the absence of air is 1058°F (570°C)]

FLAMMABLE LIMITS: LOWER 3.0% UPPER 100.0%

INSTABILITY AND REACTIVITY HAZARDS: Highly reactive. Hazardous polymerization may occur especially if contaminated. Reacts with acids, alkalies, salts, combustible materials. May undergo runaway reaction with water. Many materials may accelerate this reaction.

STORAGE RECOMMENDATIONS: Store in a cool, dry, well-ventilated location. Store away from heat, oxidizing materials, and sunlight. Separate from acids, alkalies, salts, and combustible materials. Outside or detached storage is preferred. May react in insulation forming low molecular weight polyethylene glycols that can spontaneously heat and ignite at less than 212°F (100°C).

USUAL SHIPPING CONTAINERS: Insulated steel cylinders; pressurized tanks on trucks, rail cars, barges. Safety relief valves required.

PHYSICAL PROPERTIES: Colorless gas with sweet ether-like odor.

MELTING POINT: 170°F (–112°C)

BOILING POINT: 51°F (11°C)

SPECIFIC GRAVITY: 0.89 @ 0°C

SOLUBILITY IN WATER: soluble

VAPOR DENSITY: 1.51

VAPOR PRESSURE: 1095 mm Hg @ 20°C

ELECTRICAL EQUIPMENT: Class I, Group B (C)

B-2 Nonflammable Mixtures of Ethylene Oxide.

Ethylene oxide is often mixed with a second, inert component and shipped as a liquefied gas mixture for use by sterilizer operators. Several of these mixtures are nonflammable. Table B-2 indicates the maximum amount of ethylene oxide that a nonflammable mix can contain, as well as typical ethylene oxide contents of commercially available nonflammable mixtures.

Table B-2 Nonflammable Mixtures of Ethylene Oxide*

Second Component Chemical Name	Common Name	Chemical Formula	Max. EO Wt %	Typical EO Wt %	Max. EO Vol %
Dichloro difluoromethane	CFC-12	CF_2Cl_2	12.5	12.0	28.0
Carbon Dioxide	–	CO_2	9.0	8.5	9.0
2 Chloro-2,1,1,1 Tetrafluoroethane	HCFC-124	$CHClF\text{-}CF_3$	9.3	8.6	24.2
2,1,1,1,Tetrafluoroethane	HFC-134a	CH_2FCF_3	6.1	N/A	13
2,2,1,1,1 Pentafluoroethane	HFC-125	CHF_2CF_3	8.5	N/A	21.2

*Measured in accordance with ASTM E 681, *Standard Test Method for Concentration Limits of Flammability of Chemicals*, with an ignition energy of 40 j.

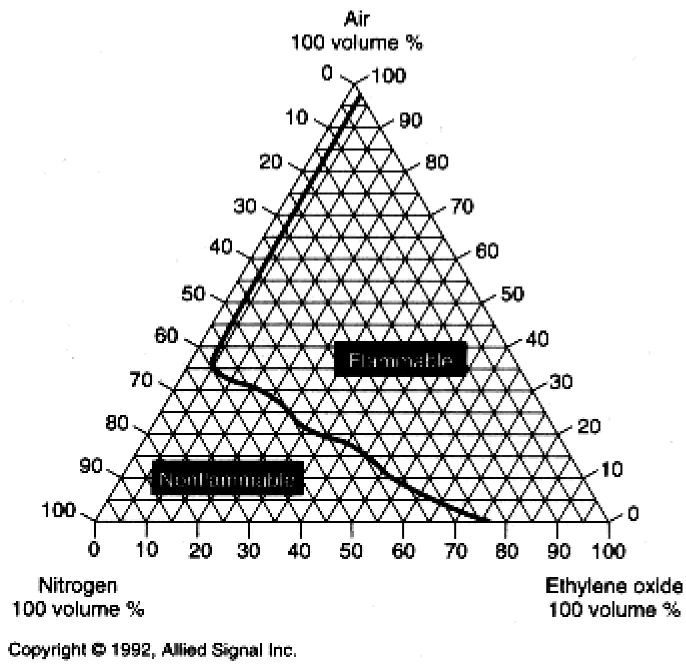


Figure B-2(a) Flammability of ethylene oxide-N_2-air mixtures at 1 atmosphere.

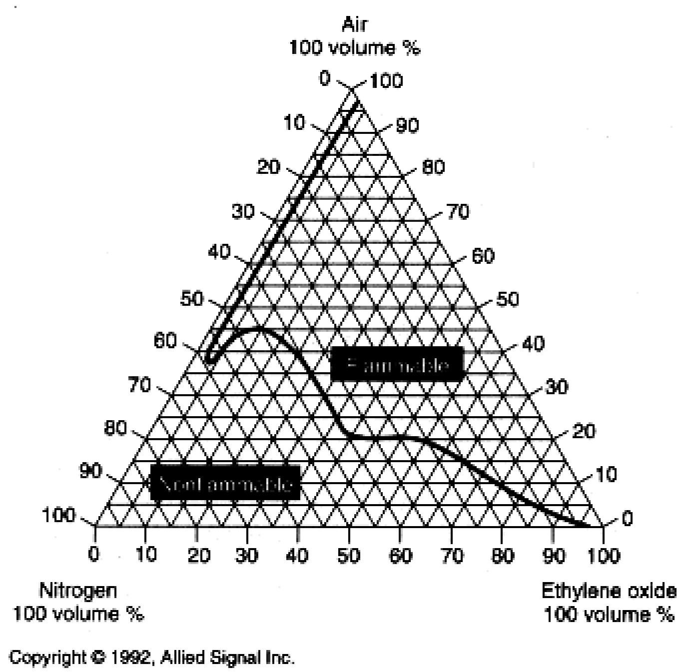


Figure B-2(b) Flammability of ethylene oxide-CO_2-air mixtures at 1 atmosphere.

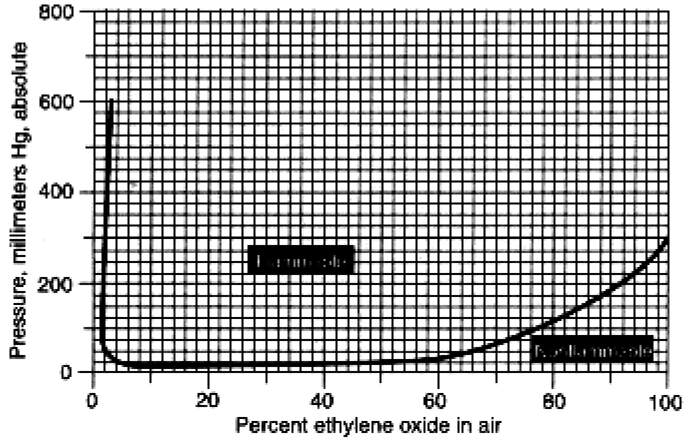


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Figure B-2(c) Flammability of ethylene oxide mixtures at subatmospheric pressures.

Appendix C Referenced Publications

C-1

The following documents or portions thereof are referenced within this standard for informational purposes only and thus are not considered part of the requirements of this document. The edition indicated for each reference is the current edition as of the date of the NFPA issuance of this document.

C-1.1 NFPA Publications.

National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.

NFPA 49, *Hazardous Chemicals Data*, 1994 edition.

NFPA 51B, *Standard for Fire Prevention in Use of Cutting and Welding Processes*, 1994 edition.

NFPA 68, *Guide for Venting of Deflagrations*, 1994 edition.

NFPA 77, *Recommended Practice on Static Electricity*, 1993 edition.

NFPA 80, *Standard for Fire Doors and Fire Windows*, 1995 edition.

NFPA 259, *Standard Test Method for Potential Heat of Building Materials*, 1993 edition.

C-1.2 Other Publications.

C-1.2.1 ASME Publications. American Society for Mechanical Engineers, 345 East 47th St., New York, NY 10017.

ASME A13.1–1981 (R1985), *Scheme for the Identification of Piping Systems*.

ASME B31.3–1993, *Chemical Plant and Petroleum Refinery Piping*.

C-1.2.2 ASTM Publication. American Society for Testing and Materials, 1916 Race St., Philadelphia, PA 19103.

ASTM E 681–1985, *Standard Test Method for Concentration Limits of Flammability of Chemicals*.

C-1.2.3 Transport Canada Publication. Transport Canada, Transport Canada Building, Place deVille Tower C, 21st Floor, Ottawa, ON K1A ON5 Canada.

Transportation of Dangerous Goods.

C-1.2.4 U.S. Government Publications. Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20401.

Code of Federal Regulations 29, 1910.119, *Process Safety Management of Highly Hazardous Chemicals* (OSHA).

Code of Federal Regulations 29, 1910.1047, *Ethylene Oxide* (OSHA).

Code of Federal Regulations 49, Parts 100-179, *Transportation*.

NFPA 600

1996 Edition

Standard on Industrial Fire Brigades

1996 Edition

This edition of NFPA 600, *Standard on Industrial Fire Brigades*, was prepared by the Technical Committee on Loss Prevention Procedures and Practices and acted on by the National Fire Protection Association, Inc., at its Fall Meeting held November 13-15, 1995, in Chicago, IL. It was issued by the Standards Council on January 12, 1996, with an effective date of February 2, 1996, and supersedes all previous editions.

Changes other than editorial are indicated by a vertical rule in the margin of the pages on which they appear. These lines are included as an aid to the user in identifying changes from the previous edition.

This edition of NFPA 600 was approved as an American National Standard on February 2, 1996.

Origin and Development of NFPA 600

In 1902 NFPA adopted *Suggestions for Organizing Private Fire Departments* recommended by the Committee on Private Fire Department Regulations. In 1912 NFPA adopted two pamphlets, *Organization and Execution of Exit Drills and Organization and Drilling of Private Fire Brigades*, on recommendation of the Committee on Private Fire Departments and Fire Drills. In 1924 the NFPA adopted *Suggestions for the Organization, Drilling and Equipment of Private Fire Brigades* on recommendation of the Committee on Field Practice, and revisions were adopted in 1930, 1937, and 1949.

Jurisdiction for the publication was transferred in 1948 to the new Committee on Fire Brigades and Watchmen, and a revised edition was published in 1955. The guide was completely revised in 1967.

In 1969 the Committee was reorganized as the Technical Committee on Loss Prevention Procedures and Practices, and the guide was reconfirmed in 1975. In 1981 a complete revision was accomplished, and partial revision was made in the 1986 edition, as well as a redesignation from NFPA 27 to NFPA 600.

In 1992 the document was completely revised to a standard to provide a minimum level of occupational safety and health for industrial fire brigade members consistent with OSHA. The standard incorporates for the first time the concepts of advanced exterior fire fighting and site-specific hazards. These are needed for industrial fire brigades to properly address the types of situations they encounter.

In 1996, the document was revised to include industrial fire departments which were previously addressed in NFPA 1500, *Standard on Fire Department Occupational Safety and Health Program*. This assists the authority having jurisdiction and owner/operators in determining which standard they must comply with and if they are in compliance. Other changes make the document more user friendly and better clarify the requirements of the standard.

Technical Committee on Loss Prevention Procedures and Practices

L. Jeffrey Mattern, *Chair*
Factory Mutual Engr Assn., PA

Carl W. Anderson, DynMcDermott, LA

Thomas L. Caisse, The Traveler’s Loss Prev. & Engr Dept., CT

Lawrence W. Davis, Jr., Industrial Risk Insurers, CT
Rep. Industrial Risk Insurers

Stanford E. Davis, PA Power & Light, PA

James N. Hearn, MD Fire and Rescue Inst., MD

John W. Kennedy, Jr., J. W. Kennedy Inc., NJ
Rep. Nat’l Assn. of Fire Equipment Distributors, Inc.

Ronald L. Kimberlin, LSU Fireman Training Program, LA

Edward P. Knopick, Jr., Gwinnett Cnty, GA

Roger A. Neal, M&M Protection Consultants, WA

Norman G. Pearson, General Motors East Regional, NY
Rep. NFPA Industrial Fire Protection Section

Craig P. Remsburg, McDonnell Douglas Aerospace, MO

Austin R. Sennett, Emergency Response Systems, MA

Michael J. Serapiglia, American Tel & Tel Co., NJ
Rep. NFPA Industrial Fire Protection Section

Robert H. Stagg, Guardsmark, Inc., NC

David E. Wacker, Princeton Insurance Co., NJ
Rep. The Alliance for Fire and Emergency Mgmt.

Larry E. Williams, Emergency Response Training Academy, Inc., AR

Larry A. Zakem, Electronic Eye Inc., OH

Alternates

Jerry L. Ball, Procter & Gamble Co., OH
(Alt. to N. G. Pearson)

Lawrence A. McKenna, Jr., American Tel & Tel Co., NJ
(Alt. to M. J. Serapiglia)

Melvin Schmidt, Chevron USA, Inc., TX
(Vot. Alt. to TIFTB Rep.)

Dean K. Wilson, Industrial Risk Insurers, CT
(Alt. to L. W. Davis, Jr.)

Nonvoting

Robert B. Bell, Dept. of Labor, Washington, DC
(Alt. to G. E. Gardner)

William J. Cherepon, Inchcape Testing Services/Caleb Brett, NJ
(Alt. to J. A. Smith-Thill)

Committee Scope: This Committee shall have primary responsibility for documents on fire brigades, guard services, and techniques for securing effective fire loss prevention programs in industrial, commercial, institutional, and similar properties.

NFPA 600

Standard on Industrial Fire Brigades

1996 Edition

NOTICE: An asterisk (*) following the number or letter designating a paragraph indicates explanatory material on that paragraph in Appendix A.
Information on referenced publications can be found in Chapter 7 and Appendix B.

Foreword

A major concern of industrial fire protection professionals is the protection of employees and property from the threat of fire in the workplace. In 1980 the Occupational Safety and Health Administration defined its requirements for fire brigades. These requirements apply to fire brigades once corporate or local management, in its role as an authority having jurisdiction, has determined that it wants a fire brigade at a facility.

In the *Code of Federal Regulations*, Title 29, Part 1910.156, Subpart L, OSHA, two types of fire brigades are defined in an attempt to establish levels of fire brigade function and to identify the training and safety requirements for each of those levels. Ever since that time industrial fire protection professionals have wrestled with categorizing every existing fire brigade into either the incipient stage category or the interior structural category.

In attempting to develop a state-of-the-art industrial fire brigade standard, the Technical Committee on Loss Prevention Procedures and Practices has followed OSHA’s lead in setting requirements based on the incipient and interior structural fire brigade definitions.

The adoption of NFPA 1500, *Standard on Fire Department Occupational Safety and Health Program*, by the NFPA in 1987 brought about an entirely new perspective — that of inclusion of the industrial fire brigades in the same category as municipal fire departments. While the work done by the Technical Committee on Fire Department Occupational Safety and Health is admirable and is intended to safeguard all fire fighters, the Loss Prevention Procedures and Practices Committee believes that a separate industrial fire brigade standard is needed.

While each and every fire brigade is unique, just as each and every municipal fire department is unique, industrial fire brigades, including those that can be referred to as industrial fire departments, have far different needs in many respects from those of municipal fire departments.

The primary difference between industrial fire brigades and municipal fire departments is that industrial fire brigades must deal with conditions and hazards that are limited to those that exist within a given facility that is generally privately owned and operated. While these site-specific hazards can and do represent the same degree of hazard to both industrial fire brigade members and municipal fire fighters, industrial fire brigade members are not usually concerned with, nor are they expected to deal with, hazards and emergencies beyond the boundaries of the facility that the brigade serves.

In addition to this primary difference, it must be remembered that at an industrial facility a program of Occupational Safety and Health has already been established for all personnel including members of the fire brigade. Further, fire brigades constituted in accordance with this standard will, of necessity, have a much more thorough knowledge of the buildings and facilities where they respond than do municipal fire fighters who must respond to a significantly greater variety of buildings and facilities, many of which have unidentified and undisclosed hazards.

A municipal fire department, as a local government function, must provide a service to a very broad-based municipality, with a multitude of unknown factors at every given response. Such variables as property size and accessibility; building size, construction, and contents; manufacturing process hazards; fixed fire extinguishing systems and special agent availability; storage and use of solvents, oils, chemicals, or other hazardous materials are all potential unknown factors that can hinder the effectiveness of any municipal fire department and place a greater safety risk on the fire fighters.

It is this distinct advantage that achieves a higher level of fire brigade safety and allows for the fundamental difference between a municipal fire department and an industrial fire brigade.

Chapter 1 General

1-1 Scope.

1-1.1

This standard contains minimum requirements for organizing, operating, training, and equipping industrial fire brigades. It also contains minimum requirements for the occupational safety and health of industrial fire brigade members while performing fire fighting and related activities.

1-1.2*

This standard shall apply to any organized private, industrial group of employees having fire fighting duties, such as emergency brigades, emergency response teams, fire teams, and plant emergency organizations.

1-1.3*

This standard shall not apply to industrial fire brigades that respond to fire emergencies outside the boundaries of the industrial facility when the off-site fire involves unfamiliar hazards or enclosed structures with layout and contents that are unknown to the fire brigade.

1-2* Purpose.

The purpose of this standard is to provide minimum requirements for organization, operation, training, and occupational safety and health for industrial fire brigades.

1-3 Alternate Requirements.

The application of the performance objectives of this standard can vary for many industrial operations. The authority having jurisdiction shall be permitted to examine and approve organization, operations, training, and occupational safety and health requirements that provide an equivalent level of safety to that required by this standard.

1-4* Limits of Actions and Responsibilities of Brigade.

1-4.1

The degree of potential exposure to a hazardous environment and the degree of training shall determine the limits of any fire brigade action and responsibility. The written fire brigade organizational statement and standard operating procedures shall define these limits.

1-4.2*

At facilities where designated employees are intended to function as the first responders to incipient fires, the fire brigade shall assume command of the incident once it arrives on the fire scene.

1-4.3 Limits for Fire Brigades Assigned Incipient Fire Fighting Duties.

1-4.3.1 Interior and exterior fires shall be considered incipient stage when fire brigade members:

(a) are able to safely fight the fire in normal work clothing, and

(b) are not required to crawl or take other evasive action to avoid smoke and heat, and

(c) are not required to wear thermal protective clothing or self-contained breathing apparatus, and

(d) are able to fight the fire effectively with portable extinguishers or handlines flowing up to 125 gpm (473 L/min).

1-4.3.2 Exterior fires shall be considered appropriate for defensive action outside of the hot and warm zones by fire brigade members who have been assigned incipient fire fighting duties when:

(a) The organizational statement lists it as a duty of the fire brigade, and it is covered by the standard operating procedures, and

(b) The fire brigade has received training for that activity, and

(c) Self-contained breathing apparatus and thermal protective clothing are not required, and

(d) Personal evasive action is not required, and

(e) They are able to perform defensive action effectively, using handlines flowing up to 300 gpm (1140 L/min), master streams, or similar devices for the manual application of specialized agents.

1-4.4 Limits for Fire Brigades Assigned Only Advanced Exterior Fire Fighting Duties.

Exterior fires shall be considered appropriate for offensive action within the hot zone by fire brigade members who have been assigned advanced exterior fire fighting duties when:

(a) The organizational statement lists it as a duty of the fire brigade, and it is covered by the standard operating procedures, and

(b) The fire brigade has received training for that activity, and

(c) Self-contained breathing apparatus and thermal protective clothing are provided, and

(d) They are able to perform offensive action effectively, using handlines flowing up to 300 gpm (1140 L/min), master streams, or similar devices for the manual application of specialized agents.

1-4.5 Limits for Fire Brigades Assigned Only Interior Structural Fire Fighting Duties.

Interior structural fires shall be permitted to be attacked within the hot zone by fire brigade members who have been assigned interior fire fighting duties when:

(a) The organizational statement lists it as a duty of the fire brigade, and it is covered by the standard operating procedures, and

(b) The fire brigade has received training for that activity, and

(c) Self-contained breathing apparatus and protective clothing for structural fire fighting are provided, and

(d) Brigade members are able to perform offensive actions effectively using handlines flowing up to 300 gpm (1140 L/min), master streams, or similar devices for the manual application of specialized agents.

1-4.6 Limits of Fire Brigades Assigned Both Advanced Exterior and Interior Structural Fire Fighting Duties.

Both exterior fires and interior structural fires shall be considered appropriate for offensive actions within the hot zone for fire brigade members who have been assigned both advanced exterior and interior fire fighting duties when:

(a) The organizational statement lists it as a duty of the fire brigade, and it is covered by the standard operating procedures, and

(b) The fire brigade has received training for that activity, and

(c) Self-contained breathing apparatus and protective clothing for structural fire fighting are provided, and

(d) They are able to perform offensive action effectively, using handlines flowing up to 300 gpm (1140 L/min), master streams, or similar devices for the manual application of specialized agents.

1-5 Definitions.

Advanced Exterior Fire Fighting. Offensive fire fighting performed outside of an enclosed structure when the fire is beyond the incipient stage (*see definition*). Advanced exterior fire fighting often requires fire brigade members to contain, control, and extinguish exterior fires involving site-specific hazards, such as flammable and combustible liquid spills or leaks, liquefied petroleum gas releases, and electrical substations. Advanced exterior fire fighting is usually performed using handlines flowing up to 300 gpm (1140 L/min), master streams, or similar devices for the manual application of specialized agents. Thermal protective clothing is required and the use of self-contained breathing apparatus (SCBA) could be required.

Approved.* Acceptable to the authority having jurisdiction.

Authority Having Jurisdiction.* The organization, office, or individual responsible for approving equipment, an installation, or a procedure.

Cold Zone. The safe area immediately surrounding and outside the boundary of the established warm zone of a fire. Personnel positioned in the cold zone are safe from the adverse effects of a fire.

Combustible Liquid. A liquid having a flash point at or above 100°F (38.8°C).

Defensive Fire Fighting. The mode of manual fire control in which the only fire suppression activities taken are limited to those required to keep a fire from extending from one area to another.

Designated Employee. An employee who is not a member of a fire brigade but who has been properly trained to use portable fire extinguishers or small hose lines to fight incipient fires in the employee's immediate work area.

Drill. An emergency exercise involving a credible emergency requiring the fire brigade to perform emergency operations.

Drug. Any substance, chemical, over-the-counter medication, or prescribed medication that affects the performance of the fire brigade member.

Duty. A fire-related service, function, or task identified in the fire brigade organizational statement and assigned to a member to perform.

Education. The process of imparting knowledge or skill through systematic instruction. It does not necessarily require formal classroom instruction.

Emergency Operations. Activities related to emergency incidents, including response to the scene of the incident and specific duties performed at the scene.

Enclosed Structure. A structure with a roof or ceiling and at least two walls that can present fire hazards to employees such as accumulations of smoke, toxic gases, and heat, similar to those found in buildings.

Fire Brigade. An organized group of employees within an industrial occupancy who are knowledgeable, trained, and skilled in at least basic fire fighting operations, and whose full-time occupation might or might not be the provision of fire suppression and related activities for their employer.

Fire Brigade Apparatus. A fire brigade emergency response vehicle designed and intended primarily for fire suppression, rescue, or other specialized function. This apparatus includes pumpers, foam apparatus, aerial ladders, rescue vehicles, and other such apparatus.

Fire Brigade Management. The individual designated by top management as being responsible for the organization, management, and functions of the industrial fire brigade.

Fire Brigade Training Coordinator. The designated company representative with responsibility for coordinating effective, consistent, and quality training within the fire brigade training and education program.

Flammable Liquid. A liquid having a flash point below 100°F (37.8°C) and having a vapor pressure not exceeding 40 psi (2068 mm Hg) at 100°F (37.8°C).

Hazardous Atmosphere. Any atmosphere that is oxygen deficient or that contains a toxic or disease producing contaminant. A hazardous atmosphere might or might not be immediately dangerous to life and health.

Hot Zone. The area immediately surrounding the physical location of a fire. The outer boundary of the hot zone extends far enough from the fire to protect fire brigade members positioned outside the hot zone from being directly exposed to flames, dense smoke, or extreme temperatures.

Incident Management System. The management system or command structure used during emergency operations to clearly identify who is in command of the incident and what roles and responsibilities are assigned to various members.

Incipient Fire Fighting. Fire fighting performed inside or outside of an enclosed structure or building when the fire has not progressed beyond incipient stage.

Incipient Stage. Refers to the severity of a fire where the progression is in the early stage and has not developed beyond that which can be extinguished using portable fire extinguishers or handlines flowing up to 125 gpm (473 L/min). A fire is considered to be beyond the incipient stage when the use of thermal protective clothing or self-contained breathing apparatus is required or a fire brigade member is required to crawl on the ground or floor to stay below smoke and heat.

Industrial Occupancy. For the purpose of this standard, industrial occupancies include industrial, commercial, mercantile, warehouse, power plant (utility), and institutional or similar occupancy, including for-profit, not-for-profit, and governmental facilities.

Interior Structural Fire Fighting.* The physical activity of fire suppression, rescue, or both, inside of buildings or enclosed structures that are involved in a fire situation beyond the incipient stage.

Master Stream. A portable or fixed fire fighting appliance supplied by either hose lines or fixed piping and that has the capability of flowing in excess of 300 gpm (1140 L/min) of water or water-based extinguishing agent.

Medically Fit. There are no known medical limitations that would interfere with the process of making decisions and providing direction while exposed to a stressful environment, as determined by a qualified physician.

Offensive Fire Fighting. The mode of manual fire control in which manual fire suppression activities are concentrated on reducing the size of a fire to accomplish extinguishment.

Performance Standards. Minimum requirements for knowledge and skills that must be provided to or demonstrated by the fire brigade member upon completion of a training or education session.

Physically Fit. As determined by a qualified physician, there are no known physical or medical limitations that would interfere with the performance of strenuous heavy lifting and pulling or with the use of self-contained breathing apparatus (SCBA) that can be required during emergency operations.

Qualified Physician. A licensed medical doctor qualified to provide professional expertise in the areas of occupational safety and health as they relate to emergency response activities.

Shall. Indicates a mandatory requirement.

Should. Indicates a recommendation or that which is advised but not required.

Site-Specific Hazard. A hazard that is present at the specific facility for which the fire brigade has been organized.

Specialized Agents. Fire extinguishing agents, such as dry chemicals, dry powders, carbon dioxide, halon, and other such non-water-based agents.

Standard. A document that contains only mandatory provisions using the word “shall” to indicate requirements. Explanatory material may be included only in the form of fine-print notes, in footnotes, or in an appendix.

Standard Operating Procedure. A written procedure that establishes a standard course of action and documents the functional limitations of the fire brigade members in performing emergency operations.

Support Member.* Personnel assigned to the fire brigade to perform specific duties, including those people who have specific technical knowledge or skills or who have been given specific assignments that indirectly support manual fire suppression efforts.

Thermal Protective Clothing. Protective clothing such as helmets, footwear, gloves, hoods, trousers, and coats that are designed and manufactured to protect the fire brigade member from the adverse effects of fire.

Training. The process of achieving proficiency through instruction and hands-on practice in the operation of equipment and systems that are expected to be used in the performance of assigned duties.

Warm Zone. The control area immediately surrounding and outside the boundary of the established hot zone of a fire. The outer boundary of the warm zone extends far enough from the outer boundary of the hot zone to protect personnel positioned outside the warm zone from the adverse effects of the fire.

Chapter 2 Requirements for All Fire Brigades

2-1 General Administration.

2-1.1* Corporate or Local Management.

Corporate or local management shall be responsible for:

(a) Evaluating the site-specific conditions and hazards to determine site-specific duties to be assigned to the fire brigade.

(b) Assigning the site-specific duties of the fire brigade.

(c) Establishing, reviewing, and maintaining a written fire brigade organizational statement.

(d) Establishing lines of authority and assigning responsibilities to ensure that the components of the fire brigade organizational statement are accomplished.

(e)* Establishing a written policy for the occupational safety and health of fire brigade members.

(f)* Establishing a written policy for the medical and job-related physical performance requirements for fire brigade members.

(g) Developing or adopting performance-based standards that establish baseline levels of proficiency in skills, knowledge, and the safety measures necessary for fire brigade members to accomplish the site-specific duties described in the fire brigade organizational statement.

(h) Developing, reviewing, and maintaining written standard operational procedures for site-specific conditions and hazards.

(i) Ensuring that a system exists to advise fire brigade management of changes in eligibility of an employee for participation on a fire brigade resulting from changes in employee's medical condition.

(j) Establishing a policy to ensure that the records required in this standard are maintained.

(k) Establishing a policy to ensure that annual funds are budgeted and available for equipment, vehicles, training and education, medical and job-related physical performance evaluations, and other necessary items to accomplish these objectives.

2-1.2

Management shall establish, review, and maintain a fire brigade organizational statement.

2-1.2.1* A written fire brigade organizational statement shall be prepared and maintained. This policy statement, which establishes the existence of the fire brigade, shall include:

(a) Basic organizational structure.

(b) The type, amount, and frequency of training and education to be provided.

(c) The expected number of members in the brigade.

(d) The duties that the brigade is expected to perform in the workplace, which define the limits of fire brigade responsibility.

(e) The shifts during which the brigade shall be available for response.

2-1.2.2* The organizational statement shall be available for inspection by the authority having jurisdiction, the fire brigade members, and their designated representatives.

2-1.3

Management shall establish lines of authority and assign responsibilities to ensure that the components of the fire brigade organizational statement are accomplished.

2-1.3.1 Management shall designate the responsible individual for the administration of the fire brigade organizational statement and the training and education program.

2-1.3.2 Management shall establish responsibility for initiating, maintaining, and enforcing standard operational procedures to ensure the safety and health of fire brigade members.

2-1.3.3 Management shall establish a policy to ensure that each fire brigade member cooperates, participates, and complies with the provisions of the fire brigade organizational statement and the training and education program.

2-1.4*

Management shall ensure that fire brigade members are a part of a corporate or local company occupational safety and health policy that identifies specific goals and objectives for the prevention and elimination of accidents, injuries, illness, and fatalities while performing fire brigade duties.

2-1.4.1 Management shall ensure that fire brigade members are adequately represented on corporate or local company occupational safety and health committees as they relate to members performing assigned fire brigade duties.

2-1.4.2* Management shall delegate the duties and responsibilities of the fire brigade safety program to a qualified individual(s).

2-1.4.3 The safety program shall include:

(a) Records and data management.

(b) Liaison with management, equipment suppliers, site or corporate safety, and medical and health departments.

(c) Development and maintenance of standard operating procedures.

(d) Accident prevention.

(e) Equipment specification and maintenance.

(f) Accident investigation.

(g) Incident scene safety.

(h) Training and education.

2-1.5*

All records associated with the operation of the fire brigade required in this standard shall be maintained in a location where they are available for inspection by the authority having jurisdiction.

2-2 General Operations.

2-2.1*

An incident management system shall be established with written procedures applying to all members involved in emergency and training operations, and shall be utilized to manage all emergency and training operations.

2-2.1.1 All members involved in emergency operations shall be familiar with the incident management system.

2-2.1.2 The incident management system shall identify roles and responsibilities relating to the safety of fire brigade operations. Safety responsibilities shall be assigned to supervisory personnel at each level of the organization.

2-2.1.3 This system shall include the roles and responsibilities of any responding public fire department and other outside agencies.

2-2.1.4* A standard system shall be used to identify and account for each fire brigade member present at the scene of the emergency.

2-2.1.5* Performance-based standards that establish minimum levels of proficiency in both skills and knowledge to permit all fire brigade members to safely accomplish the site-specific duties described in the fire brigade organizational statement shall be developed or adopted.

2-2.1.6 The incident management system shall ensure that the risk to members is evaluated prior to taking action. In situations where the risk to fire brigade members is unacceptable, the emergency response activities shall be limited to defensive operations.

Regardless of the risk, actions shall not exceed the scope of the organizational statement and standard operating procedures.

2-2.2

Standard operating procedures for site-specific conditions and hazards shall be developed, reviewed, and maintained.

2-2.2.1 These procedures shall be maintained in written form and shall address the site-specific functions identified in the fire brigade organizational statement.

2-2.2.2* These procedures shall include information regarding site-specific hazards to which fire brigade members can be exposed during a fire or other emergency.

2-2.2.3 These procedures shall address the site-specific limitations of emergency operations.

2-2.2.4 These procedures shall be accessible to all fire brigade members.

2-2.2.5 These procedures shall ensure that the shift fire brigade leader is notified of all major fire protection systems and equipment that are out of service.

2-2.3

A risk management policy for emergency response shall be established by fire brigade management.

2-2.3.1 The risk management policy shall be routinely reviewed with fire brigade members and shall be based on the following recognized principles:

(a) Some risk to the safety of fire brigade members is acceptable where there is a potential to save human lives.

(b) Minimal risk to the safety of the fire brigade members, and only in a calculated manner, is acceptable where there is a potential to save endangered property.

(c) No risk to the safety of fire brigade members is acceptable where there is no possibility of saving lives or property.

2-2.4

Operational safety requirements for fire brigade members responding to a fire emergency shall be established and shall at a minimum include the following:

(a) Personnel who are not trained in accordance with this standard shall not be permitted to enter the warm or hot zones established for a fire emergency.

(b) Self-contained breathing apparatus and thermal protective clothing shall be worn by fire brigade members entering the hot zone.

(c) Thermal protective clothing shall be worn by fire brigade members entering the warm zone.

(d) Fire brigade members shall operate in teams of two or more in response to fires that have advanced beyond the incipient stage.

(e) Fire brigade members operating in the hot and warm zones shall have an established communications system.

(f) When fire brigade members are operating in the hot zone, at least one fire brigade member with the capability to call for assistance shall remain outside the hot zone and shall maintain an awareness of the safety of fire brigade members located inside the hot zone.

(g) When fire brigade members are operating in the hot zone, additional brigade members shall be standing by in the warm zone with appropriate equipment to provide assistance or rescue.

(h) Fire brigade members positioned in the warm zone shall be clearly visible to command positions at all times.

(i) Personnel and fire brigade members positioned in any fire zone shall have reasonable opportunity to relocate to an alternate position should conditions of the fire change.

(j) Experienced fire brigade members shall oversee activities of less experienced brigade members during fire fighting operations.

2-3 General Education, Training, and Drills.

2-3.1

A training and education program shall be established and maintained for all fire brigade members to ensure that they are able to perform their assigned duties in a safe manner that does not pose a hazard to themselves or other members. All members shall be trained to a level of competency commensurate with the duties and functions that they are expected to perform, including the operation of all of the fire fighting and rescue equipment and systems they are expected to use.

2-3.2*

Members shall meet the minimum skills and knowledge requirements of a performance based training and education program. Skill levels shall be obtained by meeting documented job performance requirements for each site-specific task expected to be performed by brigade members before participating in emergency operations.

2-3.3

Fire brigade members shall not perform any duties they have not been trained and educated to perform.

2-3.4*

The quality and frequency of training and education provided shall ensure that fire brigade members are capable of performing their assigned duties in a safe manner that does not present a hazard to themselves or endanger other personnel.

2-3.5

It shall be an established goal of training and education to prevent accidents, injury, death, or illness while performing any fire brigade function.

2-3.6*

A designated fire brigade training coordinator shall provide instruction to the fire brigade or shall verify the qualifications of other instructors providing training and education to fire brigade members.

2-3.7*

Fire brigade members designated as leaders shall receive training and education commensurate with their duties. Such training and education shall be more comprehensive than that provided to the other fire brigade members.

2-3.8*

Drills shall be conducted as often as necessary to evaluate the effectiveness of the fire brigade training and education program and the competence of fire brigade members in performing assigned duties. Lessons learned shall be evaluated and documented, and additional training shall be provided as necessary to improve performance that is below established standards.

2-3.9*

The training and education provided to members shall include a review of the applicable provisions of this standard.

2-3.10

The training and education program shall include the principles and practices of fire fighting and emergency response to the extent required by the type of industrial fire brigade established and by the assignment within the brigade.

2-3.11

The training and education program shall address new hazards, equipment, and procedures introduced into the facility.

2-3.12*

Training provided to fire brigades shall develop and increase competency in life safety, property conservation, and reduction of business interruption.

2-3.13

Training shall include site-specific hazards. (*See 2-2.2.2.*)

2-3.14 Training Records.

2-3.14.1 Individual training records shall be maintained for each member of the fire brigade.

2-3.14.2 Training records shall include, but not be limited to, courses completed, subjects studied, refresher courses completed, and other evaluations of skills and knowledge, drill attendance records, and leadership or other special accomplishments related to fire brigade activities.

2-3.14.3 Training records shall be maintained and be available for inspection by the authority having jurisdiction.

2-3.14.4 Training records shall be reviewed periodically by fire brigade management and the fire brigade training coordinator to evaluate training needs and equipment needs of the brigade.

2-4 Organization of the Fire Brigade.

2-4.1

Fire brigade management shall be responsible for:

(a) Establishing programs to accomplish the items identified in the fire brigade organizational statement.

(b) Establishing the size and organization of the fire brigade.

(c) Coordinating and scheduling necessary meetings.

(d) Establishing and maintaining fire protection equipment inspection programs for fire brigade equipment.

(e) Coordinating the maintenance and review of necessary reports and records.

(f)* Maintaining liaison with local fire authorities.

(g) Making information on hazardous materials and processes to which the brigade might be exposed available to brigade members.

(h) Establishing job-related physical performance requirements for fire brigade members.

2-4.2 Fire Brigade Leader.

The fire brigade leader shall:

(a) Establish a chain of command within the brigade to act in the absence of the brigade leader.

(b) Assist in the selection process of brigade members.

(c) Establish and maintain a brigade roster.

(d) Select assistant fire brigade leaders as appropriate to the size of the brigade and keep them informed of all operations of the brigade.

(e) Develop pre-emergency plans for site-specific hazards and make information on hazardous materials and processes to which the fire brigade may be exposed available to all fire brigade members.

(f) Select and maintain equipment used by the brigade.

(g) Issue written reports on the status of the fire brigade to management, at least annually.

(h) Assist in fire investigations.

2-4.3 Assistant Fire Brigade Leaders.

The assistant fire brigade leader shall complete all tasks assigned by the fire brigade leader and substitute in his or her absence.

2-4.4 Fire Brigade Members.

2-4.4.1 Members of the fire brigade shall be selected from employees at the facility. They shall meet the requirements established for fire brigade members and shall represent as many separate areas and departments of the facility as is practical.

2-4.4.2 Each fire brigade member shall cooperate, participate, and comply with the provisions of the fire brigade organizational statement and the training and education program.

2-4.4.3 Fire brigade leaders or designated representatives shall ensure that support members are trained for their assigned duties. Support members shall demonstrate awareness of the plant's pre-fire plan prior to an incident and also shall demonstrate their assigned duties for those tasks.

2-4.5 Identification.

Members of the brigade shall be issued identification for the purpose of:

(a) Assistance in reaching the incident in an emergency.

(b) Identification by security personnel.

(c) Establishing authority.

2-4.6 Fire Brigade Communications.

(a) A means shall be established to notify brigade members of a reported incident.

(b) A means shall be established for communications between brigade members during an emergency.

2-5 Medical and Job-Related Physical Requirements.

2-5.1 General.

2-5.1.1* Prior to being accepted for fire brigade membership, employees shall be examined and certified by a qualified physician as being medically and physically fit. The medical and physical fitness requirements shall take into account the risks and the tasks associated with the individual's assigned fire brigade duties.

2-5.1.2 Fire brigade members who are under the influence of alcohol or drugs shall not participate in any fire brigade operations.

2-5.2 Medical Requirements.

Fire brigade members who perform advanced exterior fire fighting or interior structural fire fighting shall be medically evaluated by a qualified physician annually, and after each medical leave of absence.

2-5.3* Job-Related Physical Performance Requirements.

2-5.3.1* Fire brigade management shall establish job-related physical performance requirements for fire brigade members.

2-5.3.2 Fire brigade members shall meet the job-related physical performance requirements of 2-5.3.1 prior to assignment to the fire brigade.

2-5.3.3 Fire brigade members shall be evaluated annually to ensure they continue to meet the job-related physical performance requirements of 2-5.3.1.

2-5.3.4 When the evaluation required in 2-5.3.3 concludes that a fire brigade member does not meet the job-related physical performance requirements of 2-5.3.1, the member shall not be permitted to continue to perform those task specific activities.

2-5.4* Physical Fitness.

Fire brigade members shall be required to report to management any changes in their physical condition that could impact their performance as a fire brigade member.

2-6 Fire Brigade Equipment.

2-6.1

The fire brigade shall be provided with the appropriate equipment to enable it to perform the duties assigned in the organizational statement.

2-6.2*

The equipment selected shall be based on the nature of the facility and the site-specific hazards present.

2-6.3

Storage space for the fire brigade equipment shall be provided so that fire fighting equipment is readily accessible.

2-6.4

A written list shall be maintained of the equipment on the site that the fire brigade is expected to use. The list shall include the location of the equipment and procedures for obtaining the equipment when needed. This list shall be updated at least annually.

2-6.5

Operation and maintenance manuals for fire brigade equipment shall be available to the fire brigade.

2-6.6

Maintenance reports of fire brigade equipment shall be available to the fire brigade.

2-7 Fire Brigade Apparatus.

2-7.1

Fire brigade management shall consider fire brigade health and safety as primary concerns in the specification, design, construction, acquisition, operation, maintenance, inspection, and repair of all apparatus.

2-7.1.1* Fire brigade apparatus shall be operated only by members who have been qualified in its proper operation by formal training using performance-based standards.

2-7.1.2 Drivers of fire brigade apparatus shall have valid driver's licenses for the type of vehicle as required by state law or corporate policy. Vehicles shall be operated in compliance with all applicable traffic laws.

2-7.1.3 Drivers of fire brigade apparatus shall be directly responsible for safe and prudent operation under all conditions.

2-7.1.4 Standing while riding shall not be permitted.

2-7.1.5 Riding on tailsteps or in any other exposed position on fire brigade apparatus shall not be permitted.

2-7.1.6 All persons riding on fire brigade apparatus shall be seated and secured with seat belts.

2-7.2

All fire brigade apparatus shall be maintained in accordance with the manufacturer's recommendations.

2-7.3

All fire brigade apparatus shall be inspected at least weekly and within 24 hours after any use or repair to identify and correct unsafe conditions.

2-7.4

Fire brigade apparatus found unsafe shall be placed out of service until repaired.

2-7.5

Fire pumps on apparatus shall be service tested in accordance with the frequency and procedures specified in NFPA 1911, *Standard for Service Tests of Pumps on Fire Department Apparatus*.

2-7.6

All aerial devices shall be inspected and service tested in accordance with the frequency and procedures specified in NFPA 1914, *Standard for Testing Fire Department Aerial Devices*.

Chapter 3 Fire Brigades That Perform Incipient Stage Fire Fighting

3-1 General.

Fire brigades organized to perform incipient stage fire fighting shall meet the following requirements in addition to all applicable requirements of Chapters 1 and 2 of this standard.

3-2 Training.

3-2.1*

All fire brigade members shall receive training and education at least annually.

3-2.2

All fire brigade members shall participate in a drill at least annually.

3-2.3*

Training and drills involving live fire evolutions shall be performed in accordance with recognized safety precautions.

3-3 Protective Clothing and Equipment.

Thermal protective clothing and self-contained breathing apparatus shall not be required.

3-4 Medical.

Each fire brigade member shall meet the medical and job-related physical performance requirements as specified in Section 2-5.

Chapter 4 Fire Brigades That Perform Advanced Exterior Fire Fighting Only

4-1 General.

Fire brigades organized to perform advanced exterior fire fighting only shall meet the following requirements in addition to all applicable requirements of Chapters 1 and 2 of this standard.

4-2 Training and Education.

4-2.1

All fire brigade members shall receive training and education at least quarterly to meet the requirements of Section 2-3.

4-2.2

All fire brigade members shall participate in a drill at least semi-annually to meet the requirements of Section 2-3.

4-2.3

Live fire training shall be conducted at least annually. Training and drills involving a live fire evolution shall be performed in accordance with recognized safety precautions.

4-2.4

Live fire training shall include simulated props that are representative of the hazards that could be encountered by the fire brigade member.

4-3 Protective Clothing and Protective Equipment.

4-3.1

Thermal protective clothing and protective equipment shall be available in sufficient quantity and sizes to fit each brigade member expected to enter the hot and warm zones. Thermal protective clothing and protective equipment meeting the following requirements shall be required to be worn by all fire brigade members entering the hot and warm zones.

(a) Protective clothing shall be in accordance with NFPA 1971, *Standard on Protective Clothing for Structural Fire Fighting*.

(b) Helmets shall be in accordance with NFPA 1972, *Standard on Helmets for Structural Fire Fighting*.

(c) Gloves shall be in accordance with NFPA 1973, *Standard on Gloves for Structural Fire Fighting*.

(d) Footwear shall be in accordance with NFPA 1974, *Standard on Protective Footwear for Structural Fire Fighting*.

4-3.2

SCBA and PASS devices meeting the following requirements shall be provided for and shall be used by all fire brigade members working in the hot zone.

(a) PASS devices shall be in accordance with NFPA 1982, *Standard on Personal Alert Safety*

Systems (PASS) for Fire Fighters.

(b) Open-circuit type, self-contained breathing devices shall be in accordance with NFPA 1981, *Standard on Open-Circuit Self-Contained Breathing Apparatus for Fire Fighters*.

(c) Closed-circuit type, self-contained breathing devices shall be NIOSH/MSHA approved with a minimum service duration of 30 minutes and shall operate in the positive pressure mode only.

4-3.3

Protective clothing and protective equipment shall be used and maintained in accordance with manufacturer's instructions. A maintenance and inspection program shall be established for protective clothing and protective equipment. Specific responsibilities shall be assigned for inspection and maintenance.

4-3.4

Members using SCBA shall operate in teams of two or more who are in communication with each other through visual, audible, physical, safety guide-rope, electronic, or other means to coordinate their activities, and are in close proximity to each other to provide assistance in case of an emergency.

Where members are involved in operations that require the use of SCBA or other respiratory protective equipment, at least one member shall be assigned to remain outside the area where respiratory protection is required. This member shall be responsible for maintaining a constant awareness of the number and identity of personnel using SCBA, their location, function, and time of entry. Members with SCBA shall be available for rescue.

4-3.5

All fire brigade members entering the hot zone shall be provided with approved protective hoods or a combination of ear flaps and collar that provide protection for the ears and neck and interface with the self-contained breathing apparatus facepiece, thermal protective coat, and helmet.

4-4 Medical.

Each fire brigade member shall meet the medical and job-related physical performance requirements as specified in Section 2-5.

Chapter 5 Fire Brigades That Perform Interior Structural Fire Fighting Only

5-1 General.

Fire brigades organized to perform interior structural fire fighting only shall meet the following requirements in addition to all applicable requirements of Chapters 1 and 2 of this standard.

5-2 Training.

5-2.1

All fire brigade members shall receive training and education at least quarterly to meet the requirements of Section 2-3.

5-2.2

All fire brigade members shall participate in a drill at least semi-annually to meet the requirements of Section 2-3.

5-2.3

Live fire training shall be conducted at least annually. Training and drills involving a live fire evolution shall be performed in accordance with NFPA 1403, *Standard on Live Fire Training Evolutions in Structures*.

5-2.4

Live fire training shall include simulated props that are representative of the hazards that could be encountered by the fire brigade member.

5-3 Protective Clothing and Protective Equipment.

5-3.1

Protective clothing for structural fire fighting and protective equipment shall be available in sufficient quantity and sizes to fit each brigade member expected to enter the hot and warm zones. Protective clothing and protective equipment meeting the following requirements shall be required to be worn by all fire brigade members entering the hot and warm zones.

(a) Protective clothing shall be in accordance with NFPA 1971, *Standard on Protective Clothing for Structural Fire Fighting*.

(b) Helmets shall be in accordance with NFPA 1972, *Standard on Helmets for Structural Fire Fighting*.

(c) Gloves shall be in accordance with NFPA 1973, *Standard on Gloves for Structural Fire Fighting*.

(d) Footwear shall be in accordance with NFPA 1974, *Standard on Protective Footwear for Structural Fire Fighting*.

(e) PASS devices shall be in accordance with NFPA 1982, *Standard on Personal Alert Safety Systems (PASS) for Fire Fighters*.

(f) Open-circuit type, self-contained breathing devices shall be in accordance with NFPA 1981, *Standard on Open-Circuit Self-Contained Breathing Apparatus for Fire Fighters*.

(g) Closed-circuit type, self-contained breathing devices shall be NIOSH/MSHA approved with a minimum service duration of 30 minutes and shall operate in the positive pressure mode only.

5-3.2

All fire brigade members entering the hot zone shall be provided with approved protective hoods or a combination of ear flaps and collar that provide protection for the ears and neck and interface with the self-contained breathing apparatus facepiece, protective coat for structural fire fighting, and helmet.

5-3.3

Protective clothing and protective equipment shall be used and maintained in accordance with manufacturer's instructions. A maintenance and inspection program shall be established for protective clothing and protective equipment. Specific responsibilities shall be assigned for inspection and maintenance.

5-3.4

Fire brigade members performing emergency operations below ground level shall be provided with self-contained or externally supplied breathing apparatus and shall use that apparatus unless the safety of the atmosphere can be established by testing and continuous monitoring.

5-3.5

Members using SCBA shall operate in teams of two or more who are in communication with each other through visual, audible, physical, safety guide-rope, electronic, or other means to coordinate their activities, and are in close proximity to each other to provide assistance in case of an emergency.

Where members are involved in operations that require the use of SCBA or other respiratory protective equipment, at least one member shall be assigned to remain outside the area where respiratory protection is required. This member shall be responsible for maintaining a constant awareness of the number and identity of personnel using SCBA, their location, function, and time of entry. Members with SCBA shall be available for rescue.

5-4 Medical.

Each fire brigade member shall meet the medical and job-related physical performance requirements as specified in Section 2-5.

Chapter 6 Fire Brigades That Perform Both Advanced Exterior and Interior Structural Fire Fighting

6-1 General.

Fire brigades intended to perform both advanced exterior and interior structural fire fighting duties shall meet the requirements of Chapters 1, 2, 4, and 5 of this standard.

Chapter 7 Referenced Publications

7-1

The following documents or portions thereof are referenced within this standard and shall be considered part of the requirements of this document. The edition indicated for each reference is the current edition as of the date of the NFPA issuance of this document.

7-1.1 NFPA Publications.

National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.

NFPA 1403, *Standard on Live Fire Training Evolutions in Structures*, 1992 edition.

NFPA 1500, *Standard on Fire Department Occupational Safety and Health Program*, 1992 edition.

NFPA 1911, *Standard for Service Tests of Pumps on Fire Department Apparatus*, 1991 edition.

NFPA 1914, *Standard for Testing Fire Department Aerial Devices*, 1991 edition.

NFPA 1971, *Standard on Protective Clothing for Structural Fire Fighting*, 1991 edition.

NFPA 1972, *Standard on Helmets for Structural Fire Fighting*, 1992 edition.

NFPA 1973, *Standard on Gloves for Structural Fire Fighting*, 1993 edition.

NFPA 1974, *Standard on Protective Footwear for Structural Fire Fighting*, 1992 edition.

NFPA 1981, *Standard on Open-Circuit Self-Contained Breathing Apparatus for Fire Fighters*, 1992 edition.

NFPA 1982, *Standard on Personal Alert Safety Systems (PASS) for Fire Fighters*, 1993 edition.

Appendix A Explanatory Material

This Appendix is not a part of the requirements of this NFPA document but is included for informational purposes only.

A-1-1.2

This standard is intended to meet or exceed the fire brigade-related requirements of the Occupational Safety and Health Standards, Subpart L, Fire Protection (*Code of Federal Regulations*, Title 29, Chapter XVII, Part 1910), of the Occupational Safety and Health Administration (OSHA), Department of Labor-U.S. Government. Further, this standard is intended to ensure the industrial fire brigade member with an appropriate degree of occupational safety and health while performing fire brigade duties just as NFPA 1500, *Standard on Fire Department Occupational Safety and Health Program*, ensures an appropriate degree of occupational safety and health for the municipal fire department member.

For additional information on fire brigade organization, see Chapter 4 in the NFPA *Industrial Fire Hazards Handbook*.

A-1-1.3

It is the intent that fire brigade members, who are trained and qualified under the guidance of this standard, respond to familiar hazards that are common to the industrial facility being protected.

Industrial fire brigades complying with the requirements of this standard may respond to fires outside the boundaries of the industrial facility only when the fire brigade is trained and familiar with the hazards associated with the fire. For example, a fire brigade having appropriate training in accordance with this standard may respond to a fire involving an enclosed structure outside the boundaries of the industrial facility, if such response was anticipated and preplanned by brigade management. Each brigade member should be familiar with the layout and contents of the structure and be provided with the opportunity to tour the structure at least quarterly.

A-1-2

Requirements for the establishment of industrial fire brigades are established by the authority having jurisdiction.

A-1-4

It is the potential exposure and training that separate an organized fire brigade from designated employees (as defined by OSHA) who have some fire response duties in the general work area. The scope of brigade actions and responsibilities are based on the specific duties that the fire brigade members are expected to perform. If a brigade member is not expected to perform a particular fire fighting function, then management has no obligation to train or equip the fire brigade member to perform that function.

A-1-4.2

Designated employees who are intended to respond to incipient fires in their immediate work area should receive training commensurate with the duties they are expected to perform. Their responsibilities are normally limited to sounding an alarm, taking immediate action to extinguish the fire, and evacuation of the area.

A-1-5 Approved.

The National Fire Protection Association does not approve, inspect, or certify any installations, procedures, equipment, or materials; nor does it approve or evaluate testing laboratories. In determining the acceptability of installations, procedures, equipment, or materials, the authority having jurisdiction may base acceptance on compliance with NFPA or other appropriate standards. In the absence of such standards, said authority may require evidence of proper installation, procedure, or use. The authority having jurisdiction may also refer to the listings or labeling practices of an organization concerned with product evaluations that is in a position to determine compliance with appropriate standards for the current production of listed items.

A-1-5 Authority Having Jurisdiction.

The phrase “authority having jurisdiction” is used in NFPA documents in a broad manner, since jurisdictions and approval agencies vary, as do their responsibilities. Where public safety is primary, the authority having jurisdiction may be a federal, state, local, or other regional department or individual such as a fire chief; fire marshal; chief of a fire prevention bureau, labor department, or health department; building official; electrical inspector; or others having statutory authority. For insurance purposes, an insurance inspection department, rating bureau, or other insurance company representative may be the authority having jurisdiction. In many circumstances, the property owner or his or her designated agent assumes the role of the authority having jurisdiction; at government installations, the commanding officer or departmental official may be the authority having jurisdiction.

A-1-5 Interior Structural Fire Fighting.

This definition is taken from OSHA, *Code of Federal Regulations*, Title 29, Part 1910.

Rescue is the activity of removing victims by a fire brigade as part of fire fighting activities. Rescue activities requiring specialized equipment and training, such as confined space and high angle rescue, are not included in this standard.

A-1-5 Support Member.

When organizing the industrial fire brigade, management should take into consideration the need for specialized duties required in the event of a fire or related emergency and assign personnel to the brigade to ensure that these duties are accomplished.

In most cases, personnel are not expected to perform manual fire suppression activities in the event of an emergency but are expected to perform only those specialized tasks for which they have been chosen.

Some of these specialized assignments include:

(a) *Building evacuation.* Personnel are expected to perform specialized duties to ensure that personnel are safely evacuated from an enclosed structure or the facility in the event of fire. They may be known as fire brigade wardens or a variety of other titles.

(b) *Sprinkler system control.* Personnel are assigned to perform specialized duties to ensure that control of the automatic sprinkler protection system within the fire area or the facility is maintained by facility personnel in the event of fire. They may be known as fire brigade sprinkler valve operators or a variety of other titles.

(c) *Electrical power control.* Personnel are expected to perform specialized duties to ensure that control of electrical power within the fire area or the facility is maintained by facility personnel in the event of fire. They may be known as fire brigade electricians or a variety of other titles.

(d) *Utility control.* Personnel are expected to perform specialized duties to ensure that control of plant utilities (steam, water, natural gas, and other liquid or vapor piping systems) within the fire area or the facility is maintained by facility personnel in the event of fire. They may be known as fire brigade utility control technicians or a variety of other titles.

(e) *Fire pump operation.* Personnel are expected to perform specialized duties to ensure that stationary fire pumps are placed into operation or are operating properly in the event of fire. They may be known as fire brigade fire pump operators or a variety of other titles.

(f) *Salvage.* Personnel are expected to perform specialized duties to ensure that actions are taken during and after manual fire suppression activities to minimize the resultant damage from the fire. They may be known as fire brigade salvage personnel or a variety of other titles.

(g) *Traffic control.* Personnel are expected to perform specialized duties to ensure that control of foot and vehicular traffic in and around the fire area or the facility is maintained in the event of fire and to ensure that any responding agency is directed to the fire area. These operations may be accomplished by facility security personnel who have been assigned to the fire brigade.

A-2-1.1

In order to maintain the safety and operational effectiveness of the fire brigade, it should be recognized that even during times of economic stress it is necessary to provide adequate funds for proper equipment and training.

The structure of the brigade should be determined based on an analysis of all factors present in the areas where the brigade will operate, including, but not limited to:

(a) Property size;

(b) Property accessibility;

(c) Building size and construction;

(d) Building contents;

(e) Fire protection equipment;

(f) Fire hazards;

(g) Personnel safety;

(h) Public fire department assistance;

(i) Availability of personnel;

(j) Shift and vacation schedule of the facility;

(k) Other duties of the brigade (fire watch, maintenance of fire fighting equipment, etc.).

A-2-1.1(e) The establishment of a written policy for the occupational safety and health of fire brigade members is intended to help prevent accidents, injuries, and exposures, and to reduce the severity of those accidents, injuries, and exposures that do occur. It is possible that an existing corporate safety program or policy may satisfy the requirements of this standard.

A-2-1.1(f) The establishment of a written policy for medical and job-related physical performance requirements will help ensure that fire brigade members will be medically and physically capable of performing their required duties and will help to reduce the risk of injuries and illnesses.

A-2-1.2.1 Sample Fire Brigade Organizational Statements.

ABC Fire Brigade Organizational Statement

January 1990

Purpose: The ABC Fire Brigade was organized to safeguard the employees and the property of the ABC Corporation from the threat of fire. The fire brigade is intended to function as an incipient stage fire brigade as identified by the *Code of Federal Regulations*, Title 29, Part 1910, Subpart L of the Occupational Safety and Health Administration.

Membership: Anyone who works at the ABC Corporation is welcome to join the fire brigade, although certain specific members are appointed, based on their particular job and location within the facility. At the present time, there are a total of 25 members on the brigade.

Members are identified as fire fighting members and support members. Fire fighting members are expected to perform fire fighting duties, utilizing both hand portable fire extinguishers and wheeled fire extinguishers and the $1^1/_2$-in. (38-mm) hose lines stationed throughout the facility.

Support members are not expected to fight fires but are expected to perform specialized duties that are intended to support the fire fighting operations. These support functions include:

(a) Ensuring that the building is evacuated.

(b) Ensuring that sprinkler valves are open.

(c) Ensuring that the fire department is directed to the scene of the fire.

(d) Ensuring that the fire pump is operating properly.

(e) Ensuring that other logistical needs of the fire fighting members are met.

Organization: The brigade is headed by a brigade chief. A shift fire brigade leader is also assigned to each shift. In the absence of the chief, the shift chief is in charge of the brigade. During a fire incident, the shift chief or brigade chief is in charge of the incident until the

Washington Volunteer Fire Department arrives. At this time, the officer in charge of the fire department forces on scene and the shift chief will establish a joint incident command.

Functions: The primary function of the fire brigade is to perform fire fighting operations that do not exceed the capabilities of the members present to prevent fires that begin from spreading prior to the arrival of the fire department or operation of the sprinkler system.

Additional functions include the provision of advanced first aid assistance in any salvage operations that are necessary during any type of incident, including a fire, and the checking of fire protection and life safety equipment throughout the facility on a daily basis.

Training: The primary source of training for fire fighting members is that conducted within the facility by the fire brigade training officer. This training is conducted on a monthly basis, with training being done in accordance with the ISFSI *Performance Standards for Incipient Stage Fire Brigade Member II*.

Support members receive training on a bimonthly basis in the operation of the fire protection equipment, building evacuation information, and other related topics. This training is provided by the fire brigade training officer and other personnel from the facility, such as the maintenance supervisor, the emergency coordinator, and the safety director.

Safety: While this fire brigade exists to help safeguard the people and property of the ABC Corporation, the first and foremost consideration must be for the safety of the members of the fire brigade. The brigade has limited resources and training and thus has limited abilities. These limits must be recognized by all members to ensure that members are not extended beyond their capabilities or the limitations imposed by the equipment with which they must operate.

Sample Organizational Statement

ABC Company, under contract with the XYZ Corporation for management and operation of the XYZ Plant, will use an Emergency Response Team (ERT) for the protection of those facilities.

The ERT is composed of employees whose normal job duties are not that of an ERT. In the event of an emergency, ERT members will leave their normal assigned duties and assume the duties of the ERT. Responding ERT members will be grouped into teams, and designated ERT leaders (ERTLs) using the Incident Management System will direct and supervise emergency operations. The total number of available ERT members responding to an emergency will vary from two to forty depending on the particular site, the time of day, and response times. As dictated by the size and duration of the emergency, this number could increase to over one hundred with response by trained ERT members and leaders from other XYZ Plant sites.

For fires involving enclosed structures, the ERT will perform only incipient fire fighting and will not enter into a building or enclosed structure involved with fire beyond the incipient stage. For a building involved with fire beyond the incipient stage, ERT members will notify local municipal fire departments or mutual aid organizations to respond and will assist with evacuation, account for personnel, perform first aid, and protect adjacent exposures.

For emergency fire response to the site-specific hazards associated with the storage and transfer of crude oil, the ERT will perform advanced exterior fire fighting. In performing advanced exterior fire fighting, ERT members will wear protective gear and will have responsibilities for rescue, emergency first aid, isolation of fuel sources, and application of water, foam, and dry chemical from the perimeter of the fire, which does not require entry into the interior of enclosed structures involved with fire beyond the incipient stage. Emergency contractors will be employed as necessary for complex fire emergencies that are beyond the training of the ERT.

For response to site-specific hazardous materials emergencies, the ERT will perform limited functions. In performing the limited hazardous materials functions, ERT members will be provided with appropriate personal protective equipment and will approach the source of a spill or leak and attempt to contain, control, and terminate the emergency conditions for which they have been trained. Emergency contractors will be employed as necessary for complex spills, leaks, and cleanup that are beyond that for which the ERT are trained.

Each ERT member will receive training and education commensurate with the duties and functions they are expected to perform. Forty hours of fire, safety, and hazardous materials response training will be provided annually at the ERT Training Academy using established performance-based standards. Training at the academy will include, but not be limited to, hose and nozzle handling, fire fighter safety, use of protective gear, strategies and tactics, first aid, CPR, hazard identification, spill control, and live fire fighting involving flammable liquids and gases. ERT members must attend and successfully complete one ERT Training Academy before participating in emergency operations.

ERT members will receive additional fire training quarterly. Training will be provided at each of the National Oil Supply facilities by qualified personnel to meet established performance standards. Such training will include class room instruction and hands-on training that has been selected to keep ERT members familiar with site-specific equipment, systems, and standard operating procedures.

Designated ERTLs will annually receive eight hours of specialized classroom instruction and will train and function as a leader in all live fire and hazardous materials training exercises at the ERT Training Academy and at the sites. Such training will be over and above that provided to other members and will be provided by qualified personnel. Instruction will include, but not be limited to, such subjects as leadership, methods of teaching, incident command, communications, tactics and strategies, and standard operating procedures.

A-2-1.2.2 The purpose of the fire brigade organizational statement is to demonstrate management's commitment to the establishment of a fire brigade. This statement identifies all of the information pertinent to the fire brigade and is intended to provide the fire brigade member with a clear picture of the organization of the brigade and the duties that he or she is expected to perform as they relate to the fire brigade.

In addition to the information required in the organizational statement, the following information should also be included:

(a) the line of authority of each fire brigade member;

(b) the number of fire brigade leaders;

(c) the number of fire brigade instructors;

(d) a list and description of the types of awards or recognition that brigade members may be eligible to receive.

The fire brigade organizational statement is intended to represent the foundation of the fire brigade. It is much like the mission statement of the organization. Thus, everything that the brigade does should be in accordance with the information in the organizational statement. As such, the organizational statement may need periodic revision as the mission, organization, or duties of the brigade change.

A-2-1.4

Example of a safety policy statement: It is corporate or local company policy to operate an industrial fire brigade and to provide all fire brigade members with the highest possible levels of safety and health while performing their assigned fire brigade duties.

A-2-1.4.2 The determination of whether the individual will have a full-time or part-time assignment should be made by the management. This should depend on the size and structure of the fire brigade; the activity level; the level of risk in the fire brigade's work environment; and the history of accidents, injuries, occupational illness, deaths, and exposures.

A-2-1.5

Medical records shall be permitted to be stored elsewhere in accordance with company policies.

A-2-2.1

For information on incident management systems, see NFPA 1561, *Standard on Fire Department Incident Management System*.

A-2-2.1.4 Fire brigades are often organized in such a manner that they respond to the emergency scene and assemble upon arrival. A system should be established to identify each fire brigade member arriving at the emergency scene and to organize them into groups with appropriate supervision. This requires a standard system of "reporting in" at the incident and becoming a part of the organized system of operation.

A-2-2.1.5 For information on performance standards for fire brigade members, see *Performance Standards for Industrial Fire and Emergency Management Training*, ISFSI or Chapter 3 of NFPA 1001, *Standard for Fire Fighter Professional Qualifications*, or other performance standards.

A-2-2.2.2 Site-specific special hazards should be identified and itemized for the fire brigade, along with a detailed explanation of the hazard. Special hazards may involve operations or materials. Typical operations are data processing and electronic control equipment where the discharge of a special extinguishing agent may present a hazard to fire brigade members, engine test areas, paint dip, mix and storage rooms, spray booths, flammable liquid tank farms, oil quenching and machinery operations, energized electrical equipment, hazardous materials, and combustible dusts.

A-2-3.2

It is recognized that job training requirements may vary significantly from one location to another. Those requirements should be documented based on site-specific needs. In order to meet the requirements of 2-3.2, fire brigade management should perform an analysis of required fire brigade duties.

The training should be equivalent to ISFSI *Fire Suppression Training of Industrial Fire Brigade Members and Emergency Responders*; Chapter 3 of NFPA 1001, *Standard for Fire Fighter Professional Qualifications*; or other performance standards.

A-2-3.4

Management should develop a plan and schedule to provide training, education, and drills at the minimum specified frequencies required by this standard.

It is recognized that scheduling difficulties in the industrial setting will make it difficult to provide training, education, or drills on a specific day for each individual brigade member. For this reason, the following clarifications are intended to provide the necessary flexibility for planning and scheduling these activities:

(a) Quarterly requirements should be accomplished every 90 days and should not exceed 120 days between sessions.

(b) Semi-annual requirements should be accomplished every 183 days and should not exceed 243 days between sessions.

(c) Annual requirements should be accomplished every 365 days and should not exceed 455 days between sessions.

A-2-3.6

The fire brigade training coordinator should be an employee who is recognized or certified as a fire brigade or fire service instructor by a government authority or national certification organization, or the coordinator should demonstrate the competency to meet the requirements of management in its role as an authority having jurisdiction.

For information on performance standards for fire brigade instructors, see *Performance Standards for Industrial Fire and Emergency Management Training*, ISFSI or NFPA 1041, *Standard for Fire Service Instructor Professional Qualifications* or equivalent.

Where fire brigade training is contracted and provided by individuals or agencies outside of the company organization, the designated fire training coordinator should verify and ensure that instructors providing the training are knowledgeable in the subjects being presented. Such training should be accomplished using prepared lesson plans and performance-based standards that have been approved by the fire brigade training coordinator.

Employees and members of the fire brigade who have been trained in the methods of teaching and are recognized by the fire training coordinator as knowledgeable in the subject being presented may provide instruction to the fire brigade with the use of prepared lesson plans and performance-based standards that have been approved by the fire training coordinator.

The fire brigade training coordinator should oversee the fire brigade training and education program to ensure quality and consistency of the training provided.

A-2-3.7

Fire brigade leaders should be provided training on the incident management system established in 2-2.1 of this standard. For information on performance standards for fire brigade leaders, see ISFSI for fire brigade leader, Chapter 2 of NFPA 1021, *Standard for Fire Officer Professional Qualifications*, or other performance standards.

A-2-3.8

Management should designate the person(s) responsible for planning and scheduling drills based on realistic scenarios for credible site-specific emergencies.

Where mutual aid or other outside agencies play an important role in the emergency response procedures of the site, drills and pre-emergency planning should be conducted in conjunction with these agencies.

Management should designate the person(s) responsible for observing drills and for critiquing fire brigade or outside agency performance. Lessons learned should be incorporated into the training and education program to improve any performance that is below established standards.

While there are recognizable training benefits achieved through drills exercising the knowledge and skills of the fire brigade, drills should not be considered as training (*see definition of a drill*). For example, if fire brigade members were never trained in the operation of a piece of fire brigade apparatus or in the proper strategies and tactics for emergency fire operations, then the fire brigade member could not demonstrate competence in performing these tasks in a drill. Drills can be valuable in determining the frequency of refresher training necessary to maintain fire brigade skills.

Responses to actual emergencies may reduce the necessity to conduct drills, providing the actual responses occur with sufficient frequency and as long as the fire brigade performance during these responses is evaluated in accordance with established performance objectives and properly documented.

A-2-3.9

Since members will be required to meet the provisions of this standard that apply to the type of fire brigade of which they are members, it is important that the applicable provisions of this standard be reviewed in the training program.

A-2-3.12

Members of the industrial fire brigade should be afforded opportunities to improve their skills and knowledge of fire prevention and fire fighting through attendance at outside meetings and special training classes. Members who belong to volunteer fire departments and who receive certified training from a qualified instructor as a part of their public fire department activities may have this training documented in their individual fire brigade training records.

A-2-4.1(f) Fire brigade management should maintain a close working relationship with all emergency response organizations that might reasonably be expected to respond to the facility during an emergency. This relationship should include items such as:

(a) A written mutual aid agreement signed by management and the emergency response organization.

(b) Establishment of an incident management system that identifies the roles and responsibilities of both the fire brigade and the emergency response organization.

(c) Inviting the emergency response organizations to participate in a pre-fire planning walk-through or tour of the facility.

(d) Inviting the emergency response organizations to participate in fire brigade drills at least annually.

(e) Ensuring that a means of communication is established between the fire brigade and the emergency response organizations. This may be accomplished by the use of common radio frequencies, the exchange of respective portable radios, or other means.

(f) Ensuring that fire hose threads are compatible or that adequate adapters are provided and available.

(g) Knowledge by both the fire brigade and the emergency response organizations of the other's available equipment. This should include items such as water supply, pump size, foam capabilities, portable or fixed master stream devices, or both, and other specialized equipment.

A-2-5.1.1 For information on medical requirements, see OSHA requirements in the *Code of Federal Regulations*, Title 29, Part 1910.156 or NFPA 1582, *Standard on Medical Requirements for Fire Fighters*.

A-2-5.3

Minimum physical performance requirements should be established to ensure that fire brigade members are able to satisfactorily perform their assigned emergency response activities under adverse conditions.

A-2-5.3.1 Many critical emergency response activities may be physically demanding. These tasks require muscular strength, muscular endurance, aerobic capacity, flexibility, equilibrium, and anaerobic power. Fire brigade management should include the capabilities noted above for the evaluation of fire brigade members.

A-2-5.4

Fire brigade members should be encouraged to maintain good physical condition.

A-2-6.2

In selecting the equipment necessary to allow the fire brigade members to perform their duties as specified in the fire brigade organizational statement, it should be recognized that such a selection may be drawn from a wide range of equipment. The following is a sample of the equipment more commonly selected:

(a) Portable fire extinguishers. Portable fire extinguishers should be in accordance with NFPA 10, *Standard for Portable Fire Extinguishers*.

(b) Hose and hose accessories. Fire hose should be in accordance with NFPA 1961, *Standard for Fire Hose*. Hose should be maintained in accordance with NFPA 1962, *Standard for the Care, Use, and Service Testing of Fire Hose Including Couplings and Nozzles*.

(c) Portable lighting equipment. Portable lighting equipment, including portable electric generators, extension cords, electrical adapters, hand-held lights, and spare batteries.

(d) Forcible entry tools. Forcible entry tools, including axes, saws, power tools, plaster hooks, pike poles, claw tools, door openers, crowbars, sledgehammers, wire and bolt cutters, and battering rams.

(e) Ladders.

(f) Salvage and overhaul equipment.

(g) Rescue and first aid equipment.

(h) Special purpose equipment, such as portable foam- making equipment.

(i) Personnel protective equipment.

A-2-7.1.1 For information on performance standards for industrial fire brigade apparatus operators, see ISFSI Training of Industrial Fire Brigade Apparatus Operators, Chapters 2 through 6 of NFPA 1002, *Standard for Fire Department Vehicle Driver/Operator Professional Qualifications*, or other performance standards.

A-3-2.1

Training and education objectives can be accomplished in the same session.

A-3-2.3 Fire Field Safety Recommendations.

(a) Site Selection Preparation:

Select an open area with a safe clearance from important buildings, dry vegetation, and storage containers holding flammable liquids and gases and compressed gases.

(b) Safety Procedures:

1. Smoking should be permitted only in designated areas.

2. Fuel and ignition sources should be separated by safe distances.

3. If high winds or other adverse weather conditions present a hazard to members or adjacent property, live fire training should not be conducted.

4. Only appropriate ignition sources should be used.

5. Each student should utilize a charged extinguisher when participating in an evolution.

6. Fire attack should be from the upwind side.

7. Care should be taken to ensure that members are not placed at risk to the products of combustion.

8. For Class B fires, at least two portable extinguishers of the appropriate size and rating should be available for each evolution.

9. Retreat from an extinguished fire should be done in an organized manner, always being alert for possible reflash or rekindle.

(c) Fire Training Evolutions:

Evolutions should be commensurate with the size of fires that the members are expected to extinguish in their normal duties.

(d) Student Clothing:

Individuals participating in field evolutions should be attired in the type of clothing they would normally wear during the performance of their day-to-day job function.

(e) Instructors:

1. An instructor should guide each student while approaching, extinguishing, and retreating from each live fire training evolution.

2. The instructor should provide for the proper supervision of members who are not participating in the current evolution.

(f) Fuels:

1. Flammable liquids should not be used as accelerants to ignite Class A training fires.

2. Only approved safety containers should be used to dispense combustible liquids used as accelerants.

3. The person fueling and lighting the fire should be properly instructed and should wear appropriate protective clothing.

4. A qualified person equipped with a charged hand- line or appropriate extinguisher should stand by in any case where a combustible liquid is being used to light a training fire.

Appendix B Referenced Publications

B-1

The following documents or portions thereof are referenced within this standard for informational purposes only and thus are not considered part of the requirements of this document. The edition indicated for each reference is the current edition as of the date of the NFPA issuance of this document.

B-1.1 NFPA Publications.

National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.

NFPA 10, *Standard for Portable Fire Extinguishers*, 1994 edition.

NFPA 1001, *Standard for Fire Fighter Professional Qualifications*, 1992 edition.

NFPA 1021, *Standard for Fire Officer Professional Qualifications*, 1992 edition.

NFPA 1041, *Standard for Fire Service Instructor Professional Qualifications*, 1992 edition.

NFPA 1500, *Standard on Fire Department Occupational Safety and Health Program*, 1992 edition.

NFPA 1561, *Standard on Fire Department Incident Management System*, 1995 edition.

NFPA 1582, *Standard on Medical Requirements for Fire Fighters*, 1992 edition.

NFPA 1961, *Standard for Fire Hose*, 1992 edition.

NFPA 1962, *Standard for the Care, Use, and Service Testing of Fire Hose Including Couplings and Nozzles*, 1993 edition.

NFPA *Industrial Fire Hazards Handbook*, Third edition.

B-1.2 Other Publications.

B-1.2.1 Federal Regulations. U.S. Government Printing Office, Washington, DC.

Code of Federal Regulations, Title 29, Chapter XVII, Part 1910.

B-1.2.2 ISFSI Publications. International Society of Fire Service Instructors, 30 Main St., Ashland, MA 01721.

Performance Standards for Industrial Fire and Emergency Management Training.

Performance Standards for Industrial Fire and Emergency Management Training — Fire Brigade Leader.

Performance Standards for Incipient Stage Fire Brigade Member II.

NFPA 601

1996 Edition

Standard for Security Services in Fire Loss Prevention

1996 Edition

This edition of NFPA 601, *Standard for Security Services in Fire Loss Prevention*, was prepared by the Technical Committee on Loss Prevention Procedures and Practices and acted on by the National Fire Protection Association, Inc., at its Fall Meeting held November 13-15, 1995, in Chicago, IL. It was issued by the Standards Council on January 12, 1996, with an effective date of February 2, 1996, and supersedes all previous editions.

This edition of NFPA 601 was approved as an American National Standard on February 2, 1996.

Origin and Development of NFPA 601

The text dates from 1925 when the NFPA Committee on Field Practice presented a set of advisory rules called *The Watchman*, which was adopted and published by the NFPA and reprinted in 1930, 1936, and 1949. Jurisdiction for the publication was transferred in 1948 to the Committee on Fire Brigades and Watchmen, which presented revisions under the title *The Watchman, Recommended Manual of Instruction and Duties for the Plant Watchman or Guard*, which was adopted in 1951. Further amendments were adopted in 1956. In 1968, the document was revised under the title *Recommendations for Guard Service in Fire Loss Prevention*. It was at this time that NFPA 601A, *Standard for Guard Operations in Fire Loss Prevention*, was published as a separate standard.

In 1969, the Committee was reorganized as the Technical Committee on Loss Prevention Procedures and Practices.

NFPA 601 was revised in 1969, 1975, 1981, and 1986.

NFPA 601A was revised in 1981. In 1986 the document was reconfirmed and redesignated NFPA 602.

In 1992, NFPA 601 and 602 were combined for the benefit of the user.

In 1995, the standard was completely revised to reflect modern security methods, terminology, and techniques.

Technical Committee on Loss Prevention Procedures and Practices

L. Jeffrey Mattern, *Chair*
Factory Mutual Engr, Assn., PA

Carl W. Anderson, DynMcDermott, LA

Thomas L. Caisse, The Traveler's Loss Prev. & Engr Dept., CT

Lawrence W. Davis, Jr., Industrial Risk Insurers, CT
Rep. Industrial Risk Insurers

Stanford E. Davis, PA Power & Light, PA

James N. Hearn, MD Fire and Rescue Inst., MD

John W. Kennedy, Jr., J. W. Kennedy, Inc., NJ
Rep. Nat'l Assn. of Fire Equipment Distributors, Inc.

Ronald L. Kimberlin, LSU Fireman Training Program, LA

Edward P. Knopick, Jr., Gwinnett Cnty, GA

Roger A. Neal, M&M Protection Consultants, WA

Norman G. Pearson, General Motors East Regional, NY
Rep. NFPA Industrial Fire Protection Section

Craig P. Remsburg, McDonnell Douglas Aerospace, MO

Austin R. Sennett, Emergency Response Systems, MA

Michael J. Serapiglia, American Tel & Tel Co., NJ
Rep. NFPA Industrial Fire Protection Section

Robert H. Stagg, Guardsmark, Inc., NC

David E. Wacker, Princeton Insurance Co., NJ
Rep. The Alliance for Fire and Emergency Mgmt.

Larry E. Williams, Emergency Response Training Academy, Inc., AR

Larry A. Zakem, Electronic Eye Inc., OH

Alternates

Committee Scope: This Committee shall have primary responsibility for documents on fire brigades, guard services, and techniques for securing effective fire loss prevention programs in industrial, commercial, institutional, and similar properties.

NFPA 601

Standard for Security Services in Fire Loss Prevention

1996 Edition

NOTICE: An asterisk (*) following the number or letter designating a paragraph indicates explanatory material on that paragraph in Appendix A.
Information on referenced publications can be found in Chapter 7 and Appendix B.

Chapter 1 Introduction

1-1 Purpose.

Protection of persons and property against hazards of fire is a management responsibility. The requirements of this standard are intended to aid management in defining the requirements, duties, and training for individuals to perform security services to protect a property against fire loss.

1-2 Scope.

This standard shall apply to the selection, requirements, duties, and training of security personnel who will perform fire loss prevention duties. It shall cover the following three categories of security services:

(a) Protection of the property, including times when management is not present.

(b) Access and egress control into and within the confines of the protected property.

(c) Carrying out procedures for the orderly conduct of various operations at the property.

1-3 Definitions.

Approved.* Acceptable to the authority having jurisdiction.

Authority Having Jurisdiction.* The organization, office, or individual responsible for approving equipment, an installation, or a procedure.

Drill. An exercise involving a credible simulated emergency that requires security personnel to perform planned emergency operations for the purpose of evaluating the effectiveness of the training and education programs and the competence of security personnel in performing required duties and functions.

Fire Brigade. An organized group of employees who are knowledgeable, trained, and skilled in at least basic fire-fighting operations, and whose full-time occupation may or may not be the provision of fire suppression and related activities for their employer.

Fire Loss Prevention Manager. A person responsible for:

(a) The preparation and implementation of a fire loss prevention plan, and

(b) Revisions to the plan as changes occur at the site.

Hazardous Area. An area that contains a hazardous atmosphere and those areas of the structures or buildings used for processes that involve quantities of flammable liquids, liquids processed at or above their flash point, flammable gases, or explosive materials that have the potential for catastrophic loss. This includes processes that constitute a high fire hazard because of the form, character, or volume of the material used.

Hazardous Atmosphere. Any atmosphere that is oxygen deficient or that contains a toxic or disease-producing contaminant. A hazardous atmosphere may or may not be immediately dangerous to life and health.

Hot Work. Any welding, cutting, brazing, or grinding that generates sparks capable of causing combustion.

Labeled. Equipment or materials to which has been attached a label, symbol, or other identifying mark of an organization that is acceptable to the authority having jurisdiction and concerned with product evaluation that maintains periodic inspection of production of labeled equipment or materials and by whose labeling the manufacturer indicates compliance with appropriate standards or performance in a specified manner.

Listed.* Equipment or materials included in a list published by an organization acceptable to the authority having jurisdiction and concerned with product evaluation that maintains periodic inspection of production of listed equipment or materials and whose listing states either that the equipment or material meets appropriate standards or has been tested and found suitable for use in a specified manner.

Performance Standards. Minimum requirements for knowledge that must be provided to and/or demonstrated by the individual upon completion of a training program.

Protective Signaling System. Any alarm or system of alarms designed to give notification or warning, whether audible at the location or at a central receiving area, of the existence of a probable emergency or other unusual occurrence that might involve life safety or property protection.

Security. The branch of an organization, public or private, charged with the responsibility of safeguarding the assets (people, physical plant, properties, and products and reputation) of an organization. The process of security can be proprietary, contractual, or a combination of both. Proprietary security involves the use of company employees charged with the responsibility of protection. Contractual security makes use of an outside firm to supply individuals for the purpose of protection and loss prevention.

Shall. Indicates a mandatory requirement.

Should. Indicates a recommendation or that which is advised but not required.

Chapter 2 Management Responsibilities

2-1* Management Responsibilities.

Management shall have the responsibility of providing protection from the hazards of fire for persons and property. The fire loss prevention manager shall be consulted in the design and implementation of the security policies and procedures affecting fire loss prevention.

2-2* Procedures and Instructions.

Procedures and instructions involving security shall be specific with respect to duty responsibilities and actions required.

2-3 Succession to Supervisory Responsibility.

Management shall establish a clear line of succession in the event of absences.

2-4* Contract Security Service.

Supervision of security officers from outside firms shall be provided.

2-5 Maintenance of Equipment.

Management shall establish procedures for the maintenance of equipment provided for use by security personnel.

2-6* Identification.

Security officers shall be provided with a means of identifying themselves as authorized representatives of fire loss prevention management. The method of identification shall be acceptable to the authority having jurisdiction.

Chapter 3 Security Functions and Duties

3-1 General.

Where permitted by the authority having jurisdiction, security personnel shall be permitted to be supplemented or supplanted by an approved protective signaling system.

3-2 Other Duties of Security Officers.

Security officers shall be permitted to perform other duties in addition to their security responsibilities. These other duties shall not compromise the security functions.

3-3 Patrol Service.

3-3.1 Routes to be Patrolled.

3-3.1.1 Each route to be covered by a security officer shall be designated by the manager responsible.

3-3.1.2 The security officer assigned to each route shall be provided with instructions, all details regarding the route, and the functions to be carried out in covering the route.

3-3.1.3 The route shall be explicitly defined to ensure that the security officer patrols the correct area.

3-3.1.4* Security officers shall monitor hazardous areas remotely through methods acceptable to the authority having jurisdiction to afford prompt detection of fire or conditions likely to cause fire or other loss.

3-3.2 Rounds.

3-3.2.1 A security officer shall make rounds at intervals determined by management. When operations in the property normally are suspended, officers shall make rounds hourly or as assigned by management. Where special conditions exist, such as the presence of exceptional hazards or when fire protection equipment is impaired, management shall institute additional rounds.

3-3.2.2* The first round shall begin within one-half hour after the end of activities of the preceding work shift. During this round, the security officer shall make a thorough inspection of all buildings or spaces.

3-4 Control of Pedestrian and Vehicular Movement.

Security shall be established to:

(a) Prevent entry of unauthorized persons.

(b) Control the activities of people authorized to be on the property, but who are not aware of procedures established for the prevention of fire.

(c) Control pedestrian and vehicular traffic throughout the normal working day as directed by management, and during exit drills, and evacuation of the property due to emergencies.

(d) Control gates and vehicular traffic to facilitate access to the property by the public fire department, members of any private fire brigades, law enforcement, emergency medical services, and off-duty management personnel in the event of fire and other emergencies.

3-5* Fire Protection Function of Security.

Where management assigns fire protection functions to security and provides training therein, procedures shall be established for orderly conduct of the operations at the property, including procedures for fire loss prevention both by employees of the property protected and by outside contractors, and the prompt reporting of any fires discovered by calling the public fire department and the fire brigade of the property (if available on the shift).

3-6 General Duty Requirements.

3-6.1 Reporting for Duty.

Security officers shall report for duty at times specified by their superiors. When, due to illness, injury, or other causes, officers are unable to report for duty, they shall notify their superiors at the earliest possible time.

3-6.2 Fitness for Duty.

An on-duty security officer shall not accept relief by another officer who is not in a condition to work. The on-duty security officer shall ensure that the relief officer is fit for duty.

3-6.3 Emergencies on Duty.

Security officers shall not leave their assigned areas except in an emergency. In such cases, they shall notify either their superiors or another officer as soon as practicable or send an appropriate signal to a constantly attended location, such as a control center or a police or fire station.

3-7 Reports.

3-7.1 Report of Conditions Requiring Immediate Action.

Security officers shall promptly report conditions needing immediate attention, such as:

(a) Sprinkler system valves found closed, or

(b) Potential damage caused by freezing, or

(c) Process or service equipment that is believed to be out of order, or

(d) Other site-specific matters that would affect the operation or security of the facility.

These reports shall be in accordance with written instructions that indicate persons to whom reports are to be distributed and any immediate verbal notifications that are to be made.

3-7.2 Incident Reports.

Security officers shall make incident reports as required. These reports shall cover:

(a) Where — the exact location.

(b) When — the exact time.

(c) What — the act or thing done.

(d) How — the method by which an act was done.

(e) Who — the identity of the person or persons.

3-7.3* Daily Report.

Security officers shall complete daily reports as required.

Chapter 4 Selection and Conduct of Security Officers

4-1* Character Investigation.

Management shall require individuals considered for a security officer position to satisfactorily pass a character investigation.

4-2 Skills and Ability.

The applicant shall have the skills and ability to perform prescribed duties and to meet all job qualifications.

4-3* Criminal Convictions.

Applicants for a position as a security officer shall provide information on all criminal convictions, including the location of the conviction, the nature of the crime, and the judicial disposition. Prior to an offer of employment, the applicant shall furnish certified copies of criminal history checks from the location of residence for the past ten years.

4-4 Contract Service.

Contracts for security service shall include a provision stating that the service provider will replace any of its employees who, in the judgment of the company purchasing the service, are not qualified.

4-5 Medical Requirements.

The employer shall establish medical and fitness requirements based on the risks and the functions associated with the individual's duties and responsibilities.

4-6 General Conduct of Security Officers.

4-6.1 Conduct on Duty.

Security officers shall conduct themselves in such a way as not to interfere with the proper performance of their duties. They shall not sleep or consume alcohol or drugs on duty, or report for duty under the influence of alcohol or drugs.

4-6.2 Information.

Security officers shall not release any information without the approval of management.

4-6.3 Authorized Persons.

Security officers shall not release any details of their assignments except to authorized persons.

4-6.4* Enforcing Rules.

Security officers shall follow and enforce rules adopted by the management of the property.

Chapter 5 Training and Education

5-1* General.

Management shall establish an initial and ongoing performance-based training and education program for security officers to meet their assigned duties and functions.

5-2* Site-Specific Knowledge.

Management shall establish programs for security officers to ensure they are familiar with the property being protected, including:

(a) All buildings, occupancies, and hazards.

(b) Fixed fire protection systems.

(c) Manual and automatic detection and alarm systems.

(d) Portable fire protection equipment.

(e) Emergency shutdown procedures and equipment for which they are responsible.

(f) The facility emergency action plan.

5-3 Materials and Processes.

Management shall ensure that security officers are knowledgeable in site-specific hazardous materials and processes. This shall be done prior to a security officer being assigned to the hazard area and when new hazardous materials and processes are introduced into the facility. The management shall ensure that security officers are familiar with the location and interpretation of Material Safety Data Sheets.

5-4* Construction Operations.

Management shall ensure that security officers are knowledgeable in the hazards associated with construction, demolition, alteration, and repair operations.

5-5 Emergency Plans.

Management shall ensure that security officers are familiar with the site-specific emergency plans for dealing with fires and other emergencies.

5-6 Emergency Procedures.

Management shall ensure that security officers are familiar with the procedures to follow in the recognition and reporting of an emergency, including:

(a) When and how to use radio equipment, telephone, and private or public alarm boxes to summon aid.

(b) How to notify the fire brigade, the municipal fire department, and other emergency response organizations.

(c) The personnel to be contacted.

Chapter 6 Communications

6-1* Communication Systems.

Security officers shall be provided with a means for continuous communication with a constantly attended location.

6-2 Protective Signaling Systems.

Protective signaling systems, where provided, shall be installed, designed, and operated in accordance with NFPA 72, *National Fire Alarm Code*.

6-3* Security Tour Supervision Systems.

Where security tour supervision systems are provided, they shall be listed or approved, or shall conform with NFPA 72, *National Fire Alarm Code*.

6-3.1

Management shall ensure that:

(a) Security officers are not permitted to change the time record charts.

(b) The changing and review of time record charts is done by the property manager or the manager's responsible designee, such as the fire loss prevention manager.

(c) Time record charts of security officers are promptly reviewed.

(d) Files are maintained for review by representatives of any authority having jurisdiction.

(e) All irregularities are investigated, recorded, and corrective action is taken.

6-4* Directory.

A continuously updated directory of names, telephone numbers, and other information to assist in making emergency calls shall be kept at the security control center. This directory shall include the telephone numbers of key management personnel to be notified in an emergency, fire, police and emergency medical service departments, and other outside agencies needed in an emergency.

Chapter 7 Referenced Publication

7-1

The following document or portions thereof are referenced within this standard and shall be considered part of the requirements of this document. The edition indicated for the reference is the current edition as of the date of the NFPA issuance of this document.

7-1.1 NFPA Publication.

National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269–9101.

NFPA 72, *National Fire Alarm Code*, 1993 edition.

Appendix A Explanatory Material

This Appendix is not a part of the requirements of this NFPA document but is included for informational purposes only.

A-1-3 Approved.

The National Fire Protection Association does not approve, inspect, or certify any installations, procedures, equipment, or materials; nor does it approve or evaluate testing laboratories. In determining the acceptability of installations, procedures, equipment, or materials, the authority having jurisdiction may base acceptance on compliance with NFPA or other appropriate standards. In the absence of such standards, said authority may require evidence of proper installation, procedure, or use. The authority having jurisdiction may also refer to the listings or labeling practices of an organization concerned with product evaluations that is in a position to determine compliance with appropriate standards for the current production of listed items.

A-1-3 Authority Having Jurisdiction.

The phrase "authority having jurisdiction" is used in NFPA documents in a broad manner, since jurisdictions and approval agencies vary, as do their responsibilities. Where public safety is primary, the authority having jurisdiction may be a federal, state, local, or other regional department or individual such as a fire chief; fire marshal; chief of a fire prevention bureau, labor department, or health department; building official; electrical inspector; or others having statutory authority. For insurance purposes, an insurance inspection department, rating bureau, or other insurance company representative may be the authority having jurisdiction. In many circumstances, the property owner or his or her designated agent assumes the role of the authority having jurisdiction; at government installations, the commanding officer or departmental official may be the authority having jurisdiction.

A-1-3 Listed.

The means for identifying listed equipment may vary for each organization concerned with product evaluation, some of which do not recognize equipment as listed unless it is also labeled. The authority having jurisdiction should utilize the system employed by the listing organization to identify a listed product.

A-2-1

Management of any property has a responsibility for fire loss prevention and for creating detailed plans for specific actions that are to be followed in the event of a fire. This responsibility can be delegated to an individual, such as the fire loss prevention manager.

Where there is a public fire department and that department has not already initiated a pre-fire plan for the property, the management should initiate such a plan, involving the proper officers of the public fire department to develop response plans for various situations on the property. The objective should be to anticipate, as far as possible, emergencies and types of hazards that are likely to confront security officers and other personnel.

The term "fire prevention manager" is used to describe the function of the contact person in the property management. It is not necessarily intended to be a model title for all persons to whom the described responsibilities are assigned.

A-2-2

General instructions or superficial training are of little value. Detailed, understandable instructions, which should be in written form, cannot be prepared without management's investment of time, thought, and expertise.

A-2-4

The following are some of the important items to consider when choosing the security company:

(a) Does the company make a pre-employment investigation of all its employees, including a criminal history check confirmed with a check of fingerprints?

(b) Does the company make use of psychological tests, such as the Minnesota Multiphasic Personality Inventory (MMPI) or other similar instrument conducted by a person licensed to administer same for determination of applicant qualification?

(c) Does the company have a continuous training program for its officers that deals with topics relevant to the duties expected of the officers at the facility protected?

(d) Does the company have an adequate supervisory system?

(e) Does the company have a reporting system to keep the property management informed of occurrences on the protected property?

(f) Does the company have sufficient insurance to cover any incident that can occur as a result of negligence or criminal activity on the part of one of the officers? (Ask to be made an additional insured under the policy of the company selected and get a copy of the insurance certificate to protect your company.)

(g) What are the basic qualifications for employment as a security officer with the company?

(h) Does the contracting security company have good references? (Check references whenever and wherever possible, including visitation of other installations protected by the security service.)

A-2-6

Identification of security officers is necessary for outside agencies and, in larger facilities, internal personnel to rapidly identify who is authorized by the fire loss prevention manager to perform fire loss prevention duties. The form of identification should be communicated to all involved agencies during pre-planning and should be included in the facility's emergency action plan.

A-3-3.1.4 Areas where hazardous processes or materials are located might require monitoring more frequently than other areas due to the potential for immediate catastrophic loss. In addition to the protection of property, the use of remote monitoring methods reduces or eliminates the exposure of the security officer to the hazard.

A-3-3.2.2 The first round of a patrol is very important. Unless an emergency (fire, medical emergency, perimeter breech) causes the security officer to divert efforts to another location or task, the first patrol round should be taken promptly. The purpose is to gain familiarization with the patrol site, to observe what is occurring, to find events/conditions that might cause a fire or other loss to the property, and to report them, as directed in the security procedures. The matters for specific attention in the first patrol round should be outlined in the officer's instructions for the patrol and should include the monitoring of items such as:

(a) Outside doors and gates closed and secured, and windows, skylights, fire doors, and fire shutters closed.

(b) All oily waste, rags, paint residue, rubbish, and similar combustible items removed from the buildings or reported.

(c) All fire protection equipment in place and not obstructed.

(d) Aisles clear.

(e) Motors or machines not required to run continuously.

(f) All unsecured offices, conference rooms, and smoking areas checked for carelessly discarded smoking materials.

(g) All gas and electric heaters, coal and oil stoves, and other heating devices in open or unsecured areas on the premises checked.

(h) The conditions of hazardous manufacturing processes noted as assigned. The temperature of dryers, annealing furnaces, and similar equipment that continue to operate during the night and on holidays and weekends should be noted on all rounds.

(i) Flammable and combustible materials properly stored in approved containers or storage areas.

(j) All sprinkler valves open and sealed, with gauges indicating normal pressures. If not open, that fact should be reported immediately.

(k) Areas checked to determine if heating or air conditioning systems are working properly.

(l) Water faucets and air valves examined for leaks. All water faucets and air valves found leaking should be reported and recorded.

(m) Particular attention should be given to areas under construction or involved in alteration.

A-3-5

Examples of procedures for fire loss prevention include:

(a) Checking permits for hot work, including cutting and welding, and standing by, where required, to operate fire extinguishing equipment at the location of such work.

NOTE: For information on fire watchers, see NFPA 51B, *Standard for Fire Prevention in Use of Cutting and Welding Processes*.

(b) Detecting conditions likely to cause a fire, such as leaks or spills of flammable liquids and faulty equipment.

(c) Detecting conditions that reduce the effectiveness with which a fire can be controlled, such as sprinkler valves not open, obstructed sprinkler heads, water supplies impaired, or portable fire extinguishers not in place or in working order.

(d) Performing operations to ensure that fire equipment will function effectively. These can include testing automatic sprinkler and other fixed fire protection systems; testing fire pumps and other equipment related to these systems and assisting in maintenance service on this equipment; checking portable fire extinguishers and fire hose and assisting with pressure tests and maintenance service on these items; testing fire alarm equipment; and checking equipment provided on any motorized fire apparatus and making the periodic tests and maintenance operations required for it.

(e) Operating equipment provided for control and extinguishment of incipient stage fires after giving the alarm and before the response of other persons to the alarm.

(f) Monitoring receipt of signals due to the operation of protective signaling systems provided, including trouble signals.

(g) Making patrols along routes chosen to ensure surveillance of the entire property at appropriate intervals.

A-3-7.3

The daily report form should be a brief summary of the work done and the events encountered by the officer during the shift. The format of the report form can be varied to fit either company or facility policy but should be designed to ensure that all relevant information is included. The format can consist, for example, of questions that can be responded to by either “yes,” “no,” or “N/A,” with a space made available for remarks. Examples of typical questions are:

Fires in progress or property damaged?

Stations missed?

Rule violations?

Fire hazards observed?

Exits obstructed?

Doors/windows open or broken?

Fire equipment missing or inoperative?

Sprinkler system defects found?

Areas unsecured?

Exits obstructed/blocked?

Fire door blocked or inoperative?

Smoking violations discovered?

Other events noted?

A-4-1

Character background investigations involve more than taking the information provided on the application as fact. The employing agency should institute a procedure to confirm and clarify the information provided on the completed, signed application for employment. Information regarding employment, positions held, education, and residences needs to be confirmed. Information as to military service and discharge status (DD-214), if applicable, should be confirmed. Special attention should be made in regard to periods of unemployment or self-employment and confirmation obtained from an independent third party. Personal references listed by the applicant should be contacted, as well as any other individuals who might possess information as to the suitability of the individual to be a security officer. A complete employment history is desirable, but a ten-year history from the date of the application is usually acceptable.

The employer should also consider drug screening of security officers. Examinations should be in compliance with directives established by the authority having jurisdiction. Where no directives are established or in place, testing should be in compliance with the Department of Transportation (DOT) standards for a five-panel test for illegal drug identification, administered through a National Institute for Drug Abuse (NIDA) approved laboratory.

It should be noted that the DOT requirements are for illegal drugs only. Screenings are available that can determine the presence of prescription and certain over-the-counter drugs whose abuse could be counterproductive to a safe and productive work environment.

A-4-3

Although conviction of a criminal offense should not automatically disqualify an individual for employment as a security officer, the employing firm should make every effort to obtain the complete criminal conviction history of security officer applicants. States that license security officers might require a criminal history covering a specific period of time but, for nonregulated areas, a history of no less than five years should be undertaken. This should include criminal history checks from all areas lived in for the ten years preceding the application. The employer can confirm criminal history via a set of an applicant's fingerprints. Individual states that regulate security officers might not allow applicants with felony convictions or convictions involving moral turpitude to do security work. Companies in nonregulated states should use this direction as base hiring standards.

A-4-6.4

The security officer is the most visible representative of a company, whether that officer is an employee or contractor of the company. The security officer's actions directly reflect on the image of the company and the services afforded by the company. If security gives the appearance that they are "above the law," compliance with safety and security regulations could be minimal.

A-5-1

The scope of the training and education program should be established by management or the fire protection manager acting for management.

Advantage can be taken of courses for security officers offered through vocational/technical colleges, community and junior colleges, universities, and private training agencies. Companies should schedule officers so that they can take advantage of job-related training and education opportunities. Tuition reimbursement, either complete or partial, should be considered.

Security officers should be made aware of meetings that could provide job-related knowledge. These meetings might involve groups that are dedicated to fire protection, safety, loss prevention, crime prevention, or other related areas.

Facility management should have available relevant professional publications and journals in the areas of fire and general loss prevention and safety for their information as well as for use in the training and education of security officers.

Membership in the National Fire Protection Association is recommended as one source for obtaining useful publications.

All methodologies of training should be used in the training of security officers. Training bulletins, motion pictures, videotape, audiotape, and workshop formats should be used as means to further the knowledge, skills, and abilities of the security officer.

Training aids are available from various sources. Local fire departments, state fire marshals' offices, insurance organizations, and community/junior colleges and universities can be of invaluable assistance in the training of security personnel. Manuals from manufacturers of specific equipment can also be of use.

A-5-2

The use of a training officer or mentor can prove to be more beneficial than the use of print material for the initial site training of the security officer. The training officer should be an individual who best exemplifies the quality of security desired. The training officer should be thoroughly familiar with the facility protected.

A-5-4

Construction, demolition, alteration, and repair operations create temporary conditions that might alter the fire hazards and fire protection within and nearby the facilities. Furthermore, depending on the type of project, conditions might be constantly changing. Security officers should be knowledgeable of items such as:

(a) Maintenance of unobstructed fire department or fire brigade access routes throughout the facility.

(b) Clear access to fire protection equipment such as fire hydrants, automatic sprinkler and standpipe connections, standpipe hose lines, and portable fire extinguishers.

(c) Locations where cutting, welding, and other hot work operations are being conducted, or have been conducted within the last four hours of the start of the security officer's shift.

(d) Maintenance of unobstructed access to exits, and changes in exits.

(e) Proper storage of combustible materials, including flammable and combustible liquids, combustible construction materials, and debris, away from heat sources.

(f) Location of temporary heating devices.

(g) Location of roofing operations that are being conducted, or that have been conducted within 12 hours of the start of the security officer's shift.

(h) Locations with restricted access such as asbestos abatement areas.

(i) Location of impaired fire protection systems.

For additional information on fire loss prevention during construction operations, see NFPA 241, *Standard for Safeguarding Construction, Alteration, and Demolition Operations*.

A-6-1

Communications systems can use telephones, cellular telephones, telegraph, radio, and other components. For security service communications, ordinary extension telephones and portable radios can be used if sufficient personnel are provided for and if there exists a high degree of reliability of operation and maintenance of equipment. A constantly attended location is a facility that receives signals or communications and that has personnel in attendance at all times to respond to these signals or communications.

A-6-3

Supervisory services systems are designed to continually report the performance of a security officer in connection with the intervals determined by management. The following describes some of the common systems used to perform this function.

Supervised Tours

In the first case, a series of patrol stations along the security officer's intended route are successively operated by the security officer with each station sounding a distinctive signal at a central headquarters. Customarily, the security officer is expected to reach each of these stations at a definite time, and failure to do so within a reasonable grace period prompts the central station to investigate the security officer's failure to signal. Frequently, manual fire alarm boxes that ordinarily transmit four or five rounds of signals for fire can also be actuated by a special watch key carried by the security officer to transmit only a single round to the central station, thus signaling that the box has been visited.

Deliberate distribution of stations will compel a security officer to take a definite route through the premises, and variations from that route would appear as misplaced signals on the recording tape. A further advantage is that the order of station operation can be varied from time to time in the interests of security or to meet special conditions within the building.

Compulsory Tours

In the second case, one or more stations are connected to the central station, and preliminary mechanical stations condition the security officer's key to operate the connected station after, and only after, the preliminary stations have been operated in a prearranged order. This second arrangement is somewhat less flexible than the first, but has the advantage of the absence of interconnection between the preliminary stations and, thus, the reduction of signal traffic. The usual arrangement is to have the security officer transmit only start and finish signals that must be received at the central point at programmed reception times.

Delinquency Indicators

Delinquency indicator systems contain a series of connected stations that transmit a signal if the security officer does not reach the particular station within the anticipated preset period.

A-6-4 Security Control Center.

A control center provides a point at which security officers can monitor electronic systems, sensors, or video cameras to provide prompt detection of problems or potential problems. The center should have the ability to communicate with and monitor points outside the property as well as points within the protected property.

Staffing the Security Control Center. Where the communication equipment, including equipment used on patrol, requires that communications from security officers be monitored, the control center should be provided with an operator. Additional operators and around-the-clock operator service should be provided at the control center according to the character of the security service provided. Security officers who can be dispatched to investigate signals should also be provided as necessary. The control center should not go unstaffed during times when the control center is operational.

Appendix B Referenced Publications

B-1

The following documents or portions thereof are referenced within this standard for informational purposes only and thus are not considered part of the requirements of this document. The edition indicated for each reference is the current edition as of the date of the NFPA issuance of this document.

B-1.1 NFPA Publications.

National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.

NFPA 51B, *Standard for Fire Prevention in Use of Cutting and Welding Processes*, 1994 edition.

NFPA 241, *Standard for Safeguarding Construction, Alteration, and Demolition Operations*, 1993 edition.

NFPA 650

1990 Edition

Standard for Pneumatic Conveying Systems for Handling

Combustible Materials

1990 Edition

This edition of NFPA 650, *Standard for Pneumatic Conveying Systems for Handling Combustible Materials*, was prepared by the Technical Committee on Fundamentals of Dust Explosion Prevention and Control, released by the Correlating Committee on Dust Explosion Hazards, and acted on by the National Fire Protection Association, Inc. at its Fall Meeting held November 13-15, 1989 in Seattle, WA. It was issued by the Standards Council on January 12, 1990, with an effective date of February 5, 1990, and supersedes all previous editions.

The 1990 edition of this document has been approved by the American National Standards Institute.

Changes other than editorial are indicated by a vertical rule in the margin of the pages on which they appear. These lines are included as an aid to the user in identifying changes from the previous edition.

Origin and Development of NFPA 650

NFPA 650 had its origin as NFPA 66, *Standard for Pneumatic Conveying Systems for Handling Feed, Flour, Grain and Other Agricultural Dusts*. NFPA 66 was adopted as a tentative standard in 1963, and as a standard in 1964. Revised standards were adopted in 1970 and 1973.

NFPA 650-1984, *Standard for Pneumatic Conveying Systems for Handling Combustible Materials*, in addition to being different in title from NFPA 66, differs in scope and represents a complete rewrite of NFPA 66. The rewrite makes the standard applicable to the pneumatic conveying of combustible materials, both agricultural and non-agricultural.

The 1990 edition of NFPA 650 is a reconfirmation of the 1984 edition.

Technical Committee on Dust Explosion Hazards

Correlating Committee

Thomas E. Frank, Factory Mutual Engr. Assn.

Robert W. Nelson, Industrial Risk Insurers

Anthony G. Martino, Cargill, Inc.

Technical Committee on Fundamentals of Dust Explosion Prevention and Control

Robert W. Nelson, *Chairman*
Industrial Risk Insurers

A. Richard Albrecht, Dow Chemical Co.

C. James Dahn, Safety Consulting Engineers, Inc.

John T. Higgins, Dow Corning Corp.

David C. Kirby, Union Carbide Corp.

Larry J. Moore, Factory Mutual Research Corp.

Michael E. Mowrer, Professional Loss Control Inc.

Parker Peterson, Fenwal Inc.

R. F. Schwab, Allied-Signal Inc. Rep. Society of Plastics Industries

NFPA 650
Standard for
Pneumatic Conveying Systems for Handling Combustible Materials

1990 Edition

NOTE: An asterisk (*) following the number or letter designating a paragraph indicates explanatory material on that paragraph in Appendix A.

Information on referenced publications can be found in Chapter 9 and Appendix B.

Chapter 1 General

1-1 Scope.

1-1.1

This standard shall apply to the pneumatic conveying of combustible materials.

1-1.2

This standard shall not apply to the pneumatic conveying of materials covered by:

NFPA 43A, *Code for the Storage of Liquid and Solid Oxidizing Materials, (Class 3 and 4 oxidizing materials only)*

NFPA 61A, *Standard for the Prevention of Fire and Dust Explosions in Facilities Manufacturing and Handling Starch*

NFPA 61B, *Standard for the Prevention of Fires and Explosions in Grain Elevators and Facilities Handling Bulk Raw Agricultural Commodities*

NFPA 61C, *Standard for the Prevention of Fire and Dust Explosions in Feed Mills*

NFPA 61D, *Standard for the Prevention of Fire and Dust Explosions in the Milling of Agricultural Commodities for Human Consumption*

NFPA 65, *Standard for the Processing and Finishing of Aluminum*

NFPA 85F, *Standard for the Installation and Operation of Pulverized Fuel Systems*

NFPA 120, *Standard for Coal Preparation Plants*

NFPA 480, *Standard for the Storage, Handling, and Processing of Magnesium*

NFPA 482, *Standard for the Production, Processing, Handling, and Storage of Zirconium*

NFPA 495, *Code for the Manufacture, Transportation, Storage and Use of Explosive Materials*

NFPA 651, *Standard for the Manufacture of Aluminum and Magnesium Powder*

NFPA 664, *Standard for the Prevention of Fires and Explosions in Wood Processing and Woodworking Facilities.*

1-2 Purpose.

1-2.1

The purpose of this standard is to prescribe reasonable requirements for safety to life and property from fire and explosion and to minimize the resulting damage should a fire or explosion occur.

1-2.2

This standard is not intended to prevent the use of systems, methods, or devices that provide equivalent protection from fire and explosion, providing that suitable data is available to demonstrate equivalency.

1-3 Retroactivity.

This standard applies to facilities on which construction is begun subsequent to the date of publication of this standard. When major replacement or renovation of existing facilities is planned, provisions of this standard shall apply.

1-4 Definitions.

For the purposes of this standard, the following terms shall have the meanings given below.

Approved. Acceptable to the “authority having jurisdiction.”

NOTE: The National Fire Protection Association does not approve, inspect or certify any installations, procedures, equipment, or materials nor does it approve or evaluate testing laboratories. In determining the acceptability of installations or procedures, equipment or materials, the authority having jurisdiction may base acceptance on compliance with NFPA or other appropriate standards. In the absence of such standards, said authority may require evidence of proper installation, procedure or use. The authority having jurisdiction may also refer to the listings or labeling practices of an organization concerned with product evaluations which is in a position to determine compliance with appropriate standards for the current production of listed items.

Authority Having Jurisdiction. The "authority having jurisdiction" is the organization, office or individual responsible for "approving" equipment, an installation or a procedure.

NOTE: The phrase "authority having jurisdiction" is used in NFPA documents in a broad manner since jurisdictions and "approval" agencies vary as do their responsibilities. Where public safety is primary, the "authority having jurisdiction" may be a federal, state, local or other regional department or individual such as a fire chief, fire marshal, chief of a fire prevention bureau, labor department, health department, building official, electrical inspector, or others having statutory authority. For insurance purposes, an insurance inspection department, rating bureau, or other insurance company representative may be the "authority having jurisdiction." In many circumstances the property owner or his designated agent assumes the role of the "authority having jurisdiction"; at government installations, the commanding officer or departmental official may be the "authority having jurisdiction."

Combustible Dust.* Any finely divided solid material 420 microns or smaller in diameter (material passing a U. S. No. 40 Standard Sieve) that presents a fire or explosion hazard.

Detachment. In the open air or in a separate building.

Duct. That part of a system that conveys air to or from primary and/or secondary air-material separators.

Header. That part of a system located between the air discharge of a primary or secondary air-material separator and the air intake of the prime air mover (blower or fan), which conveys the air discharge from only a single separator at any one time.

Hybrid Mixture. A combination of combustible dust and flammable gas or vapor that can be ignited.

Labeled. Equipment or materials to which has been attached a label, symbol or other identifying mark of an organization acceptable to the "authority having jurisdiction" and concerned with product evaluation, that maintains periodic inspection of production of labeled equipment or materials and by whose labeling the manufacturer indicates compliance with appropriate standards or performance in a specified manner.

Listed. Equipment or materials included in a list published by an organization acceptable to the "authority having jurisdiction" and concerned with product evaluation, that maintains periodic inspection of production of listed equipment or materials and whose listing states either that the equipment or material meets appropriate standards or has been tested and found suitable for use in a specified manner.

NOTE: The means for identifying listed equipment may vary for each organization concerned with product evaluation, some of which do not recognize equipment as listed unless it is also labeled. The "authority having jurisdiction" should utilize the system employed by the listing organization to identify a listed product.

Manifold. A header that simultaneously serves more than one air-material separator on a suction-type pneumatic system and that normally operates at a negative pressure.

Multiple Strand. The arrangement of several suction-type pneumatic systems served by a single manifold.

Pneumatic Conveying System. A system consisting of an enclosed tubing system in which a material is transported by a stream of air having a sufficiently high velocity to keep the conveyed material in motion. Noncombustible, nonreactive gases may be used in place of, or mixed with, air.

Such systems are of two principal types or a combination of the two types.

(a) *Positive Pressure-Type.* Pressure-type systems transport material by utilizing air at greater than atmospheric pressure. Such systems basically consist of a blower drawing air through a filter; an air-lock feeder for introducing materials into the system; tubing or ducts; and a suitable air-material separator.

(b) *Negative Pressure-Type.* Negative pressure-type systems transport material by utilizing air at less than atmospheric pressure. These systems basically consist of a material and air intake; tubing or ducts; a suitable air-material separator; and a fan or blower.

Primary Air-Material Separator. A collector that removes the bulk of the product or material from the conveying air stream.

Secondary Air-Material Separator. A device for removing the residual dust or product remaining in the air stream after the primary air-material separator.

Tubing. The part of a system located between the point of infeed and the primary air-material separator through which heavy concentrations of product are conveyed.

1-5 General Design.

1-5.1

All system components shall be conductive. Bonding and grounding shall be provided. (*See NFPA 77, Recommended Practice on Static Electricity*.)

1-5.2

All electrical equipment in and around the pneumatic system shall be designed and installed in accordance with NFPA 70, *National Electrical Code*®.

1-5.3

All systems shall be designed to be air-tight and dust-tight except at openings designed for intake and discharge of air and material.

1-5.4

Where more than one material is to be handled by a system, compatibility tests shall be run; and where incompatibility is found, provisions shall be made for cleaning of the system prior to transport of a new material.

1-5.5

Equipment and bins shall be provided with explosion prevention or explosion protection in accordance with either 1-5.5.1, 1-5.5.2, or 1-5.5.3.

1-5.5.1 Explosion venting may be provided. (*See NFPA 68, Guide for Venting of Deflagrations*.)

1-5.5.2 The container and system may be designed to contain the explosion pressure.

1-5.5.3 Explosion prevention systems in accordance with NFPA 69, *Standard on Explosion Prevention Systems*, may be installed.

1-5.6 Hybrid Mixtures.

1-5.6.1* Where inert gas is used, oxygen monitors shall be required and shall sound an alarm at a preset level.

1-5.6.2 When hybrid mixtures are transported, recycling of the gas stream to any work space shall not be permitted.

Chapter 2 Tubing, Headers, Manifolds, Ducts

2-1* Design.

2-1.1

Where a system or any part of a system operates as a positive pressure-type system and the blower discharge pressure is 15 psig (103 kPa) or greater, the system shall be designed in accordance with ASME *Boiler and Pressure Vessel Code*, Section VIII or ANSI/ASME B31.3, *Chemical Plant and Petroleum Refinery Piping*.

2-1.2 Elbows.

2-1.2.1 All elbows shall be of air- and dust-tight construction.

2-1.2.2 Joints shall be butted squarely and air- and dust-tight.

2-1.3

All parts of a system located within buildings shall be permanently assembled with no temporary connections that may be left open and permit the escape of material from the system.

2-1.4

Connections between individual lengths, elbows, or other pneumatic equipment shall be air- and dust-tight.

2-1.5 Support.

2-1.5.1 All tubing, headers, manifold, and ducts shall be supported so as to avoid excessive stress or strain.

2-1.5.2 Supports shall be designed to include the weight of the system and the transported material.

2-1.5.3 Vertical runs through floors shall be securely fastened at each floor level.

2-1.5.4 Tubing or ducts that pass through fire barrier or fire walls shall be rigidly supported on both sides, and the opening around the duct shall be sealed to the full thickness of the wall with a material of a fire resistance rating equivalent to that of the wall.

2-1.6 Sight Glasses.

2-1.6.1 Sight glasses, if installed, shall be of a material that is not readily damaged. Tubing shall be supported above and below each sight glass so that the sight glass does not carry any of the system weight and is not subject to stress or strain.

2-1.6.2 The electrical bonding of the system shall be continuous around all sight glasses. The strength of the sight glass and its mounting mechanism and its inside diameter shall be equal to the adjoining tube system.

2-1.6.3 Connections between the sight glass and tubing shall be butted squarely and sealed so as to be air-tight and dust-tight.

2-1.7

All tubing, headers, manifolds, and ducts shall be provided with access panels for examining and cleaning of system in accordance with NFPA 91, *Standard for the Installation of Blower and Exhaust Systems for Dust, Stock, and Vapor Removal or Conveying*.

Chapter 3 Valves

3-1 Pressure Relief Valves.

One or more relief valves for both positive pressure and negative pressure pneumatic systems shall be located, sized, and set to relieve at pressures designed to protect the system components. Valves to protect the blower package shall be installed on the clean air side of the system.

3-2 Multiple Direction Valves.

Multiple direction valves shall be of air- and dust-tight construction and shall effect a positive diversion of the conveyed product. Diversion of the product in one direction shall mechanically and automatically seal all other directions from air and dust leakage.

3-3 Air Flow Control Valves.

3-3.1

Air flow control valves installed in multiple strand suction-type pneumatic systems shall be of air- and dust-tight construction and shall inject sufficient static resistance to allow air flow adjustment for system balancing purposes. Valves shall be sized to pass the total air flow of the system with dampers in the wide open position. Valves shall be so constructed as to totally shut off air flow in the system.

3-3.2

Valves shall have visible scales to indicate the position of control dampers.

3-3.3

Manually adjusted valves shall have a locking device to prevent movement of dampers once set.

Chapter 4 Air-Material Separators

4-1 General.

4-1.1

Air-material separators that are located outside and on top of structures shall be provided with lightning protection in accordance with NFPA 78, *Lightning Protection Code*.

4-1.2

Material discharge outlets from air-material separators shall be provided with a positive choke device.

4-1.3

Exhaust air from air-material separators shall be discharged outside of building.

Exception No. 1: Where provision is made to recycle transport air directly back into the pneumatic conveying system.

Exception No. 2: Where all ducts returning air to the building are equipped and protected as indicated in 4-1.4.

4-1.4 Return Air Ducts.

4-1.4.1 Ducts shall be equipped with a filter other than the primary or secondary air-material separator.

4-1.4.2 Filters shall have a 99.5 percent efficiency for particle sizes of 1.0 micron diameter and greater.

4-2 Construction.

4-2.1

Air-material separators shall be constructed of noncombustible materials.

Exception: Filter media may be of combustible material.

4-2.2

Air-material separators shall be constructed so as to eliminate internal ledges or other points of dust accumulation. Hopper bottoms shall be sloped, and the discharge conveying system shall be designed to handle maximum flow.

4-2.3

Cleanout doors or panels shall be provided for access to the interior.

4-2.4

Air-material separators shall be provided with explosion relief. (*See NFPA 68, Guide for Venting of Deflagrations*.)

Exception: When protection is provided in accordance with 4-4.1, 4-4.2, or 4-4.3.

4-3 Location.

Air-material separators shall be located outside of buildings.

Exception No. 1: Separators may be located inside of buildings if located adjacent to an exterior wall and vented to the outside through straight and short ducts, not exceeding 10 ft (3.05 m) in length, designed according to information contained in NFPA 68, Guide for Venting of Deflagrations, and designed so that explosion pressures will not rupture the ductwork or the separator.

Exception No. 2: Separators protected in accordance with Section 4-4.

4-4* Protection.

4-4.1

Air-material separators may be equipped with an explosion suppression system. The explosion suppression system shall be designed and installed in accordance with NFPA 69, *Standard on Explosion Prevention Systems*.

4-4.2

Air-material separator systems may be designed to operate using an inert or oxygen deficient gas as a transfer medium provided that such systems are designed and installed in accordance with NFPA 69, *Standard on Explosion Prevention Systems*.

4-4.3

Air-material separators may be designed to withstand maximum peak explosion pressure.

Chapter 5 Feeding Methods

5-1 Hoppers.

When material is introduced into the pneumatic system through a hopper and feeding device, such hopper shall be dust-tight and designed for pressure equalization.

5-2* Mechanical Devices.

Mechanical feeding devices shall be equipped with a shear pin or overload detection device and alarm.

5-3 Drives.

All drives used in connection with feeders, air locks, and other devices shall be direct connected.

Exception: Belt or other indirect-type drives designed to have a sufficient service factor to stall the driving forces without slipping, and providing for the removal of static electric charges.

Chapter 6 Fans and Blowers

6-1 Design and Installation.

6-1.1

Fans and blowers shall be designed and installed in accordance with NFPA 91, *Standard for the Installation of Blower and Exhaust Systems for Dust, Stock, and Vapor Removal or Conveying*.

6-1.2

Bearings or bearing housings shall be designed to prevent overheating, oil leakage, and dust infiltration.

6-2 Maintenance.

6-2.1

Bearings shall be lubricated and checked for excessive wear on a periodic basis.

6-2.2

When the product has a tendency to stick to the rotor or housing, the rotor shall be cleaned periodically to maintain good balance, and the housing shall be cleaned periodically to minimize the possibility of ignition, especially when exposed to heated air.

6-2.3

The interior surfaces of fan housings shall be maintained free from rust. Aluminum paint shall not be used on interior steel surfaces that may be struck by foreign material because of potential heat of impact.

6-3 Operation.

6-3.1

Fans and blowers shall run at full speed before material is transported and after the material has ceased to be transported to clear the system of material.

6-3.2

Fans and blowers shall be checked periodically for excessive heat and vibration.

6-3.3

An interlock shall be provided to stop the material feed upon failure of the conveying system.

Chapter 7 Portable Conveying Units, Including Bulk Trucks

7-1 Engine and Motor Driven Equipment.

7-1.1

Engine and motor driven equipment used in confined hazardous areas shall be equipped with safety devices designed to reduce the potential fire hazard and electrical shock hazard.

7-1.2*

Requirements for engine and motor driven equipment shall meet or exceed the requirements of the *Firesafety Standard for Powered Industrial Trucks Including Type Designations, Areas of Use, Maintenance and Operation*, NFPA 505, for the following designations:

(a) Diesel powered units — Type DS.

(b) Electrical powered units — Type EE.

(c) Gasoline powered units — Type GS.

(d) Liquefied petroleum gas powered units — Type LPS.

(e) Dual powered units — Type GS/LPS.

7-1.3

Spark arrestors shall be used on the exhaust stacks of all diesel powered units.

7-1.4

Refueling shall be conducted outdoors.

7-1.5*

Surface dust shall be removed from engine and motor driven equipment at regular intervals during operation.

7-1.5.1 Cleaning with compressed air shall not be conducted in Class II hazardous locations.

7-1.5.2 Spark arrestors shall be cleaned or replaced according to the manufacturer's recommendations.

7-1.6

Maintenance procedures shall comply with the manufacturer's instructions, especially with regard to replacement of insulation, covers, electrical enclosures, and parts of the electrical system designed to reduce chafing of insulation or termination failure.

7-2 Bonding and Grounding.

7-2.1

All equipment, such as truck, tank or hopper, conveyor tube, motor, or compressors, on a unit shall be electrically bonded and grounded.

7-2.2

Flexible tubing shall be electrically conductive. Connections from the transport vehicle to the receiving system shall be made on the outside of any building.

7-2.3

The operator shall ground the truck and bond the receiving tube to the truck and receiving equipment before starting the compressor. The compressor shall be at operating speed before transporting material.

7-2.4

Portable equipment electrical bonds shall be checked visually each time the equipment is used.

7-3 Dust Control.

7-3.1

The receiving bin or hopper shall have filtered open vents.

Exception: Filters may be omitted if the bin vent is piped back to the truck.

Chapter 8 Training and Inspection

8-1 Employee Training.

8-1.1

There shall be policies and requirements that provide for initial and continuing training for all employees. These shall include the development of operating procedures that are reviewed by the management at least once per year and after every process change.

8-1.2

All employees shall be carefully and thoroughly instructed at scheduled intervals regarding the hazards of their working environment. Their reactions in cases of equipment or process failures may reduce the incidence of fires and prevent explosions.

8-2 Periodic Inspection.

8-2.1

A thorough systematic inspection for safe operation of items listed in 8-2.2 shall be made at regular intervals and shall be submitted to plant management for review.

8-2.2

The inspection shall include, but not be limited to, the following:

(a) fire and explosion protection and prevention equipment;

(b) dust control equipment;

(c) housekeeping;

(d)* electrical and mechanical equipment, relief valves, and interlocks;

(e) procedures.

8-2.3

Competent persons shall conduct such inspections and the record of their findings and recommendations shall be recorded in the principal plant office.

Chapter 9 Referenced Publications

(*See Appendix B for other referenced publications that are advisory and thus do not constitute part of the requirements of this document*.)

9-1

The following documents or portions thereof are referenced within this standard and shall be considered part of the requirements of this document. The edition indicated for each reference is the current edition as of the date of the NFPA issuance of this document.

9-1.1 NFPA Publications.

National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.

NFPA 43A-1980, *Code for the Storage of Liquid and Solid Oxidizing Materials* (1-1.2)

NFPA 61A-1989, *Standard for the Prevention of Fire and Dust Explosions in Facilities Manufacturing and Handling Starch* (1-1.2)

NFPA 61B-1989, *Standard for the Prevention of Fires and Explosions in Grain Elevators and Facilities Handling Bulk Raw Agricultural Commodities* (1-1.2)

NFPA 61C-1989, *Standard for the Prevention of Fire and Dust Explosions in Feed Mills* (1-1.2)

NFPA 61D-1989, *Standard for the Prevention of Fire and Dust Explosions in the Milling of Agricultural Commodities for Human Consumption* (1-1.2)

NFPA 65-1987, *Standard for the Processing and Finishing of Aluminum* (1-1.2)

NFPA 69-1986, *Standard on Explosion Prevention Systems* (1-5.5.3, 4-4.1, 4-4.2)

NFPA 70-1987, *National Electrical Code* (1-5.2)

NFPA 78-1986, *Lightning Protection Code* (4-1.1)

NFPA 85F-1988, *Standard for the Installation and Operation of Pulverized Fuel Systems* (1-1.2)

NFPA 91-1990, *Standard for the Installation of Blower and Exhaust Systems for Dust, Stock and Vapor Removal or Conveying* (2-1.7, 6-1.1)

NFPA 120-1988, *Standard for Coal Preparation Plants* (1-1.2)

NFPA 480-1987, *Standard for the Storage, Handling, and Processing of Magnesium* (1-1.2)

NFPA 482-1987, *Standard for the Production, Processing, Handling, and Storage of Zirconium* (1-1.2)

NFPA 495-1985, *Code for the Manufacture, Transportation, Storage and Use of Explosive Materials* (1-1.2)

NFPA 505-1987, *Firesafety Standard for Powered Industrial Trucks* (7-1.2)

NFPA 651-1987, *Standard for the Manufacture of Aluminum and Magnesium Powder* (1-1.2)

NFPA 664-1987, *Standard for the Prevention of Fires and Explosions in Wood Processing and Woodworking Facilities* (1-1.2).

9-1.2 Other Publications.

9-1.2.1 ANSI Publication. American National Standards Institute, 1430 Broadway, New York, NY, 10018.

ANSI/ASME B31.3-1976, *Chemical Plant and Petroleum Refinery Piping* (2-1.1)

9-1.2.2 ASME Publication. American Society of Mechanical Engineers, 345 East 47th Street, New York, NY, 10017.

ASME *Boiler and Pressure Vessel Code,* Section VIII (2-1.1)

Appendix A

This Appendix is not a part of the requirements of this NFPA document, but is included for information purposes only.

A-1-4 Combustible Dust.

Any time a combustible dust is processed or handled, a potential for explosion exists. The degree of explosion hazard will vary depending on the type of combustible dust and processing methods used.

A dust explosion has four requirements:

(a) A combustible dust,

(b) A dust dispersion in air or oxygen at or exceeding the minimum explosion concentration, and

(c) An ignition source such as a static, RF, or electric spark or arc; a glowing ember dust layer, hot surface, or weld slag; a friction heated bearing, pulley, rotor, fan; a flame or other source.

(d) *Confinement.* Evaluation of the hazard of a combustible dust should be determined by the means of actual test data. All combustible dusts that may produce a dust explosion should be tested so as to determine the following data:

(1) Particle size distribution.
(2) Moisture content as received and dried.
(3) Minimum dust concentration to ignite.
(4) Minimum energy required for ignition (joules).
(5) Maximum rate of pressure rise at optimum concentration.
(6) Layer ignition temperature.
(7) Maximum explosion pressure, at optimum concentration.
(8) Electrical resistivity measurement.
(9) Dust cloud ignition temperature.

Optional Testing.

(10) Maximum permissible oxygen content to prevent ignition.

A-1-5.6.1 For oxygen concentration levels see NFPA 69, *Standard on Explosion Prevention Systems*.

A-2-1

Ducts should be equipped, where applicable, with an automatic spark detection and extinguishing system.

A-4-4

Air-material separators containing combustible component parts should be equipped with an automatic sprinkling device in accordance with NFPA 13, *Standard for Installation of Sprinkler Systems*, or other special extinguishing system in accordance with NFPA 12, *Standard on Carbon Dioxide Extinguishing Systems*; NFPA 12A, *Standard on Halon 1301 Fire Extinguishing Systems*; or NFPA 12B, *Standard on Halon 1211 Fire Extinguishing Systems*.

A-5.2

Magnetic or other protective separating equipment should be provided to prevent entrance of ferrous materials into the pneumatic system. Removal of nonferrous material should be by screen or gravity separator or other device.

A-7-1.2

Refer to the following publications for further information:

UL 558, *Standard for Internal Combustion Engine Powered Industrial Trucks*.

UL 583, *Standard for Electric Battery Powered Industrial Trucks*.

(FM) *Approval Standard for Gasoline or Diesel Engine Powered Industrial Trucks, Types G, GS, D, or DS*.

(FM) *Approval Standard for Electrical Battery Powered Industrial Trucks, Types E and EE*.

(FM) *Approval Standard for LP-Gas Engine Powered Industrial Trucks, Types LP and LPS*.

ANSI/ASME B56.1, *Safety Standard for Powered Industrial Trucks*.

A-7-1.5

Cleaning should be done at 1-hour intervals during periods of steady operation and at the end of each work day.

A-8-2.2

(d) Safety interlocks should be calibrated and tested at scheduled intervals in the manner in which they are intended to operate with written test records maintained and reviewed by management.

Appendix B Referenced Publications

B-1

The following documents or portions thereof are referenced within this standard for informational purposes only and thus are not considered part of the requirements of this standard. The edition indicated for each reference is the current edition as of the date of the NFPA issuance of this document.

B-1.1 NFPA Publications.

National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.

NFPA 12-1989, *Standard on Carbon Dioxide Extinguishing Systems* (A-4-4)

NFPA 12A-1989, *Standard on Halon 1301 Fire Extinguishing System* (A-4-4)

NFPA 12B-1985, *Standard on Halon 1211 Fire Extinguishing Systems* (A-4-4)

NFPA 13-1989, *Standard for the Installation of Sprinkler Systems* (A-4-4)

NFPA 68-1988, *Guide for Venting of Deflagrations* (1-5.5.1, 4-2.4, 4-3 *Exception No. 1)*

NFPA 69-1986, *Standard on Explosion Prevention Systems* (A-1-5.6.2)

NFPA 77-1988, *Recommended Practice on Static Electricity* (1-5.1)

B-1.2 Other Publications.

B-1.2.1 ANSI Publication. American National Standards Institute, 1430 Broadway, New York, NY, 10018.

ANSI/ASME B56.1, *Safety Standard for Powered Industrial Trucks* (A-7-1.2)

B-1.2.2 FM Publications. Factory Mutual Research Corportation, 1151 Boston-Providence Turnpike, Norwood, MA 02062.

Approval Standard for Electrical Battery Powered Industrial Trucks, Types E and EE (A-7-1.2)

Approval Standard for Gasoline or Diesel Engine Powered Industrial Trucks, Types G, GS, D or DS (A-7-1.2)

Approval Standard for LP-Gas Engine Powered Industrial Trucks, Types LP and LPS (A-7-1.2)

B-1.2.3 UL Publications. Underwriters Laboratories Inc., 333 Pfingsten Rd., Northbrook, IL 60062.

UL 558, *Standard for Internal Combustion Engine Powered Industrial Trucks* (A-7-1.2)

UL 583, *Standard for Electric Battery Powered Industrial Trucks* (A-7-1.2)

Appendix C Schematics of Typical Pneumatic Conveying Installations

This Appendix is not a part of the requirements of this NFPA document, but is included for information purposes only.

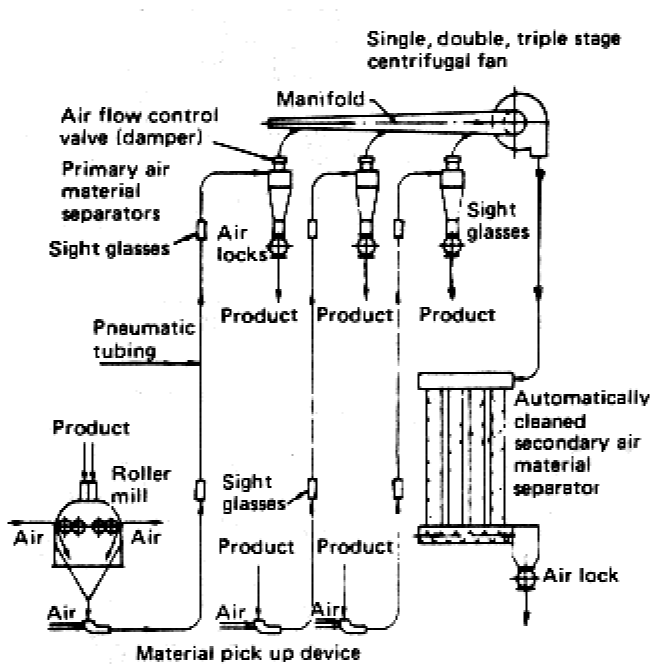


Figure C-1 Multiple strand system, NEGATIVE PRESSURE-TYPE, typical for cereal mills.

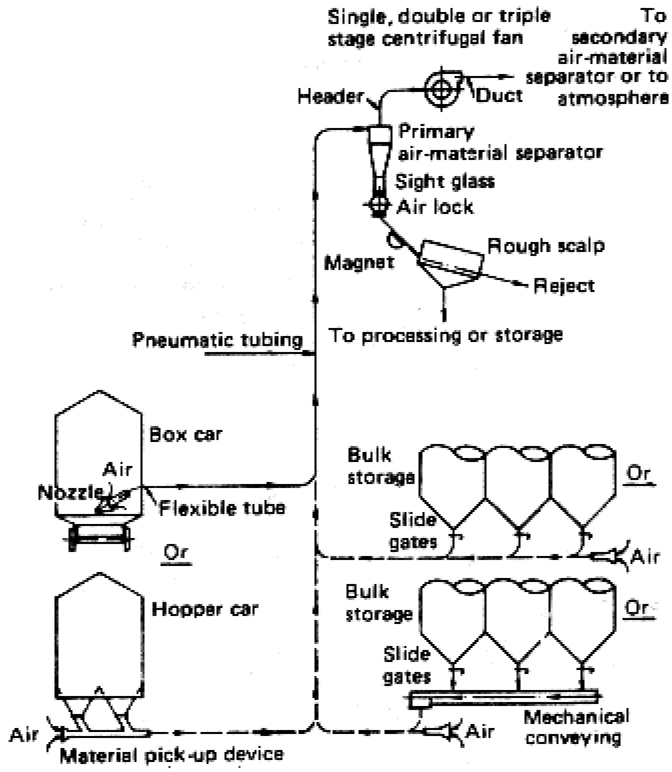


Figure C-2 Typical car unloader system, NEGATIVE PRESSURE-TYPE, low capacity.

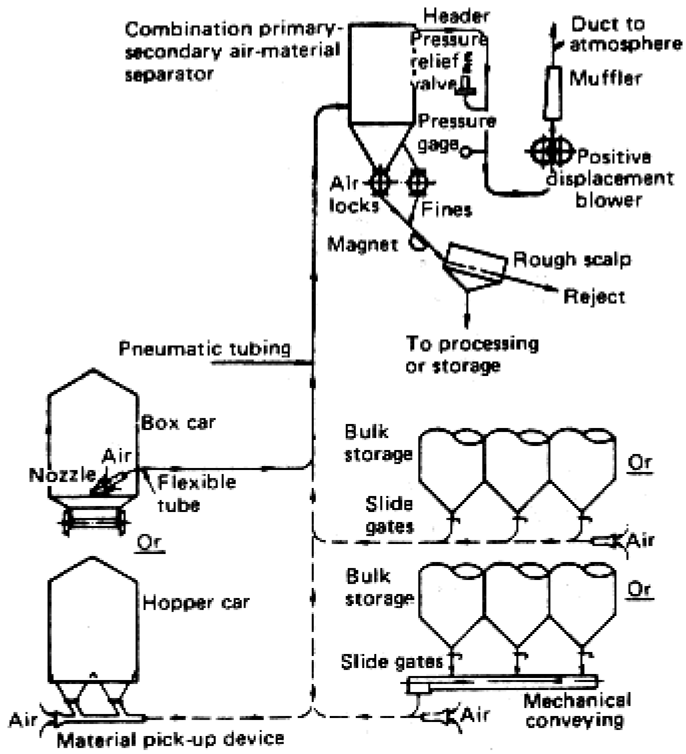


Figure C-3 Typical car unloader system, NEGATIVE PRESSURE-TYPE, high capacity.

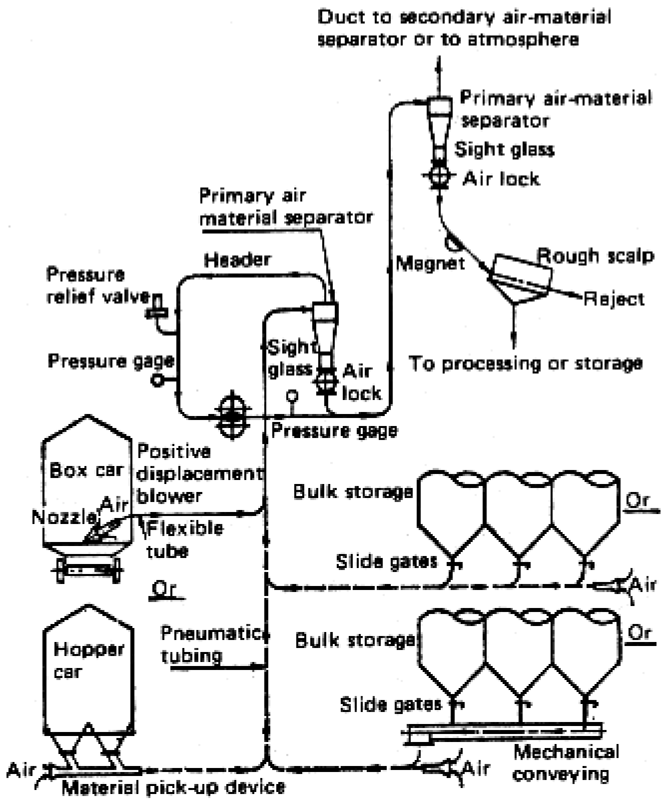


Figure C-4 Portable car unloader and transfer system, combination NEGATIVE PRESSURE-TYPE, and POSITIVE PRESSURE-TYPE, high capacity.

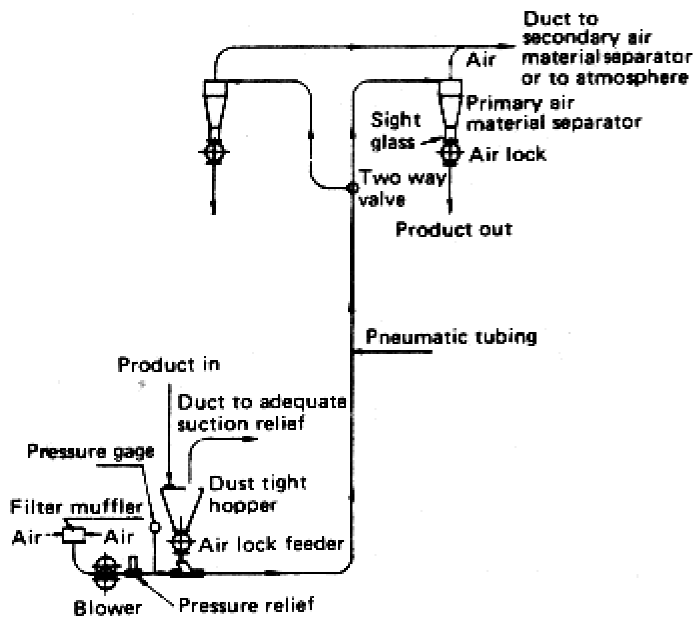


Figure C-5 Typical transfer system, POSITIVE PRESSURE-TYPE, high capacity.

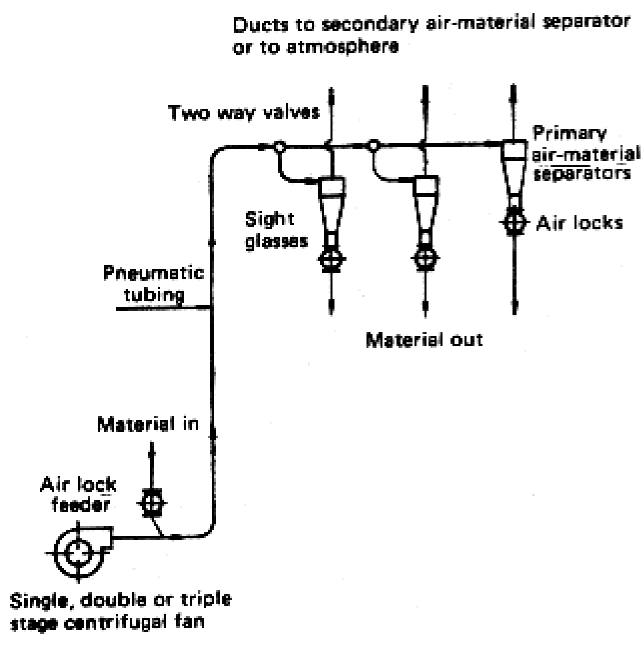


Figure C-6 Typical transfer system, POSITIVE PRESSURE-TYPE, low capacity.

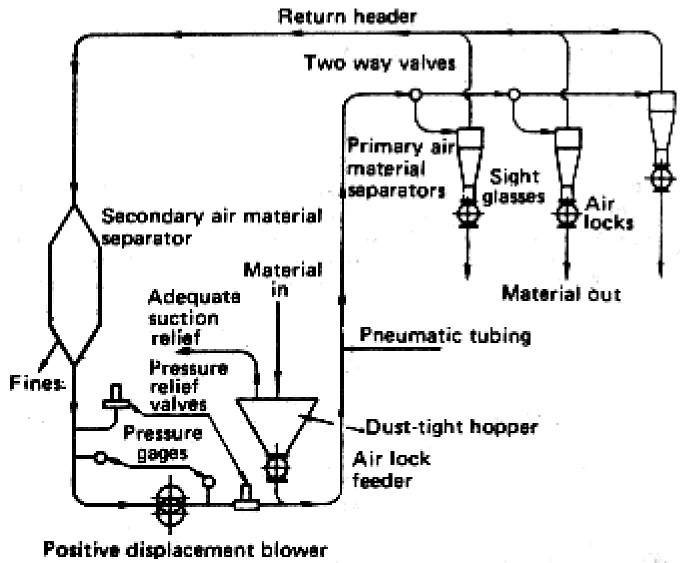


Figure C-7 Typical recirculating transfer system, POSITIVE PRESSURE-TYPE, high capacity.

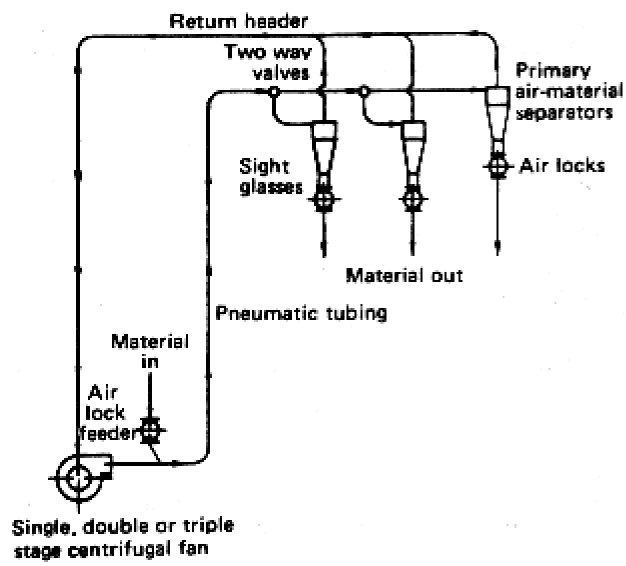


Figure C-8 Typical recirculating transfer system, POSITIVE PRESSURE-TYPE, low capacity.

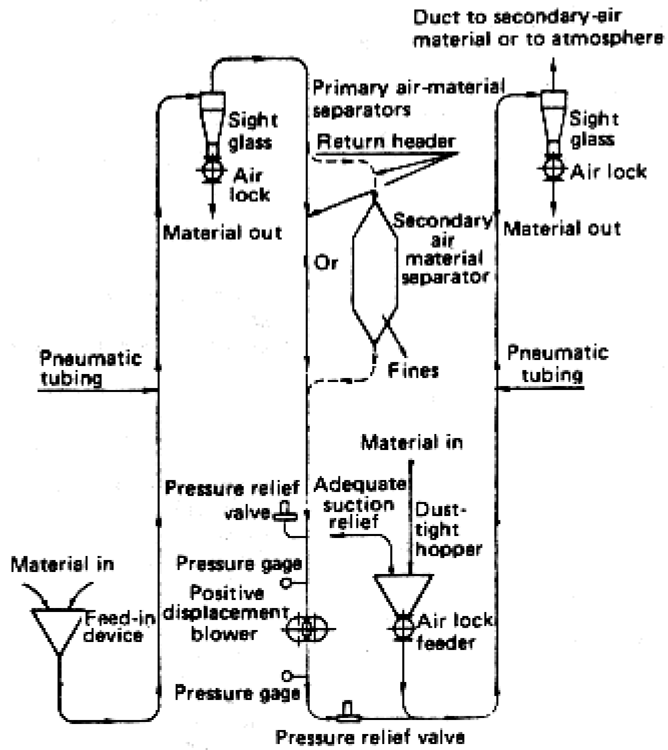


Figure C-9 Typical transfer system, combination POSITIVE PRESSURE-TYPE and NEGATIVE PRESSURE-TYPE, high capacity.

NFPA 651

1993 Edition

Standard for the Manufacture of Aluminum Powder

1993 Edition

This edition of NFPA 651, *Standard for the Manufacture of Aluminum Powder,* was prepared by the Technical Committee on Combustible Metals and Metal Dusts and acted on by the

National Fire Protection Association, Inc. at its Annual Meeting held May 24-27, 1993, in Orlando, FL. It was issued by the Standards Council on July 23, 1993, with an effective date of August 20, 1993, and supersedes all previous editions.

The 1993 edition of this document has been approved by the American National Standards Institute.

Changes other than editorial are indicated by a vertical rule in the margin of the pages on which they appear. These lines are included as an aid to the user in identifying changes from the previous edition.

Origin and Development of NFPA 651

NFPA 651, *Manufacture of Aluminum Powder*, was originally prepared by the Committee on Dust Explosion Hazards in 1938 and 1939. It was first adopted in 1939, and revised in 1946, 1952, 1959, 1963, 1967, and 1972. The 1967 edition was approved by the American National Standards Institute in 1967 and designated ANSI Z12.11.

NFPA 652, *Plants Producing or Handling Magnesium Powder*, was originally prepared by the Committee on Dust Explosion Hazards in 1942 and was first adopted in 1944. Amendments were adopted in 1945, 1946, 1952, 1959, and 1968. The 1968 edition was approved by the American National Standards Institute in 1968 and designated ANSI Z12.15.

In 1973 NFPA 651 and 652 were combined into a single standard, NFPA 651-T, and tentatively adopted at the 1973 Annual Meeting and officially adopted at the 1974 Annual Meeting. Revisions were adopted in 1980 and 1987.

For this 1993 edition, the Committee has added definitions, clarified the requirements for the location of aluminum powder production plants, revised the requirements for electrical power, machinery and operations, and for in-plant conveying of aluminum powder including the provisions for inert conveying. The requirements for explosion venting, manual fire fighting, and automatic sprinkler protection were also updated. This includes the change in terminology from “light metal powder” to “aluminum powder” to emphasize that the requirements for the manufacture of magnesium powder have now been incorporated into the 1993 edition of NFPA 480, *Standard for the Storage, Handling and Processing of Magnesium Solids and Powders*. The Committee has incorporated various style and editorial revisions to comply with the NFPA *Manual of Style* and to assist in making the document more usable, adoptable, and enforceable.

Technical Committee on Combustible Metals and Metal Dusts

Robert W. Nelson, *Chair*
Industrial Risk Insurers, CT
Rep. Industrial Risk Insurers

Richard J. Biehl, Ansul Fire Protection, WI
Rep. Fire Equipment Manufacturers’ Assn., Inc.

R. Thomas Currin, FMC Corp., NC

Edward A. Gadsby, Cyprus Foote Mineral Co., VA

Ron A. Kirsch, Occupational Health Services Inc., TN

Edward S. Krupinski, Sedgwick James of Arizona Inc., AZ

Kevin M. Laporte, Uni-Wash Inc., MI

John E. McConaghie, Reade Manufacturing Co., NJ

Neil T. Morgan, Naval Undersea Warfare Engineering Station, WA

Eldon Poulsen, Timet/TDA, NV

Charles F. Reade, Reade Advanced Materials, RI

James A. Robertson, Dow Chemical Co. USA, TX

Peter E. Rogers, Wolcott, VT

Joseph B. Scheller, Silberline Mfr. Co. Inc., PA
Rep. The Aluminum Assn.

Waldemar Seton, SJO Consulting Engineers, OR

John Valiulis, Factory Mutual Research Corp., MA

Alternates

Edward D. Leedy, Industrial Risk Insurers, IL
(Alt. to R. W. Nelson)

Larry J. Moore, Factory Mutual Research Corp., MA
(Alt. to J. Valiulis)

Martha H. Curtis, NFPA Staff Liaison

This list represents the membership at the time the Committee was balloted on the text of this edition. Since that time, changes in the membership may have occurred.

NOTE: Membership on a Committee shall not in and of itself constitute an endorsement of the Association or any document developed by the Committee on which the member serves.

Committee Scope: This Committee shall have primary responsibility for documents on safeguards against fire and explosion in the manufacturing, processing, handling and storage of combustible metals, powders and dusts.

NFPA 651
Standard for the

Manufacture of Aluminum Powder

1993 Edition

NOTICE: An asterisk (*) following the number or letter designating a paragraph indicates explanatory material on that paragraph in Appendix A.
Information on referenced publications can be found in Chapter 9 and Appendix C.

Chapter 1 General

1-1 Scope.

1-1.1*

This standard shall apply to manufacturing facilities that produce aluminum flake powder, aluminum paste, atomized aluminum powder or aluminum granules, or any aluminum alloy powder that is combustible or explosive in an ambient atmosphere.

1-1.2

This standard shall not apply to the production of waste metal dust by operations such as grinding, buffing, and polishing of semifinished aluminum products. (*See NFPA 65, Standard for the Processing and Finishing of Aluminum.*)

1-1.3

This standard does not apply to the transportation of aluminum powder on public highways, waterways, or by air or rail.

1-2 Purpose.

The objective of this standard is to minimize the occurrence of and resulting damage from fire and explosion in areas where aluminum powder products are manufactured.

1-3 Retroactivity.

Unless otherwise stated, the requirements of this standard shall not be applied retroactively.

1-4 Equivalent Protection.

1-4.1

Existing plants, equipment, structures, and installations that do not comply strictly with the requirements of this standard shall be considered to be in compliance if it can be shown that an equivalent level of protection has been provided or that no specific hazard will be created or continued through noncompliance.

1-4.2

This standard is not intended to prevent use of systems, methods, or devices that provide equivalent protection from fire and explosion. NFPA 69, *Standard on Explosion Prevention Systems*, shall be referred to when considering the use of optional systems.

1-5 Definitions.

Approved. Acceptable to the “authority having jurisdiction.”

NOTE: The National Fire Protection Association does not approve, inspect or certify any installations, procedures, equipment, or materials nor does it approve or evaluate testing laboratories. In determining the acceptability of installations or procedures, equipment or materials, the authority having jurisdiction may base acceptance on compliance with NFPA or other appropriate standards. In the absence of such standards, said authority may require evidence of proper installation, procedure or use. The authority having jurisdiction may also refer to the listings or labeling practices of an organization concerned with product evaluations which is in a position to determine compliance with appropriate standards for the current production of listed items.

Authority Having Jurisdiction. The "authority having jurisdiction" is the organization, office or individual responsible for "approving" equipment, an installation or a procedure.

NOTE: The phrase "authority having jurisdiction" is used in NFPA documents in a broad manner since jurisdictions and "approval" agencies vary as do their responsibilities. Where public safety is primary, the "authority having jurisdiction" may be a federal, state, local or other regional department or individual such as a fire chief, fire marshal, chief of a fire prevention bureau, labor department, health department, building official, electrical inspector, or others having statutory authority. For insurance purposes, an insurance inspection department, rating bureau, or other insurance company representative may be the "authority having jurisdiction." In many circumstances the property owner or his designated agent assumes the role of the "authority having jurisdiction"; at government installations, the commanding officer or departmental official may be the "authority having jurisdiction."

Combustible Aluminum Dust.* Any finely divided aluminum material 420 microns or smaller in diameter (material passing a U.S. No. 40 Standard Sieve) that presents a fire or explosion hazard when dispersed and ignited in air.

Labeled. Equipment or materials to which has been attached a label, symbol or other identifying mark of an organization acceptable to the "authority having jurisdiction" and concerned with product evaluation, that maintains periodic inspection of production of labeled equipment or materials and by whose labeling the manufacturer indicates compliance with appropriate standards or performance in a specified manner.

Listed. Equipment or materials included in a list published by an organization acceptable to the "authority having jurisdiction" and concerned with product evaluation, that maintains periodic inspection of production of listed equipment or materials and whose listing states either that the equipment or material meets appropriate standards or has been tested and found suitable for use in a specified manner.

NOTE: The means for identifying listed equipment may vary for each organization concerned with product evaluation, some of which do not recognize equipment as listed unless it is also labeled. The "authority having jurisdiction" should utilize the system employed by the listing organization to identify a listed product.

Shall. Indicates a mandatory requirement.

Should. Indicates a recommendation or that which is advised but not required.

Chapter 2 Location and Construction of Aluminum Powder Production Plants

2-1 Location.

2-1.1

Aluminum powder production plants shall be located on a site large enough so that the buildings in which powder is manufactured are at least 300 ft (90.9 m) from public roads and from any occupied structure, such as public buildings, dwellings, business or manufacturing establishments, other than those buildings that are a part of the aluminum powder production plant.

2-1.2

Different powder production systems shall be located in separate buildings located at least 50 ft (15.2 m) from each other.

Exception: Two buildings less than 50 ft (15.2 m) apart shall be permitted if the facing walls of the exposed building shall be capable of resisting a blast pressure of 2.0 psig (13.8 kPa gauge) and shall be nonload-bearing, noncombustible, and without openings.

2-2 Security.

2-2.1

This section shall be applied to new and existing facilities.

2-2.2

The site on which the powder production plant is located shall be surrounded by strong fencing at least 6 ft (2 m) high with suitable entrance gates.

2-2.3

All gates that are not kept locked shall be under supervision.

2-3 Building Construction.

2-3.1

All buildings used for the manufacture, packing, or loading for shipment of aluminum powders shall, where practical, be single story, without basements, constructed of noncombustible materials throughout, and have nonload-bearing walls. The buildings shall be designed so that all internal surfaces are readily accessible to facilitate cleaning.

2-3.2

All buildings used for the manufacture of aluminum powders shall be subdivided into as many small units as practical by pressure-resistant, nonload-bearing, noncombustible, dusttight walls.

2-3.3

All walls of areas where dust can be produced, which are not of monolithic construction, shall have all masonry joints thoroughly slushed with mortar and troweled smooth so as to leave no interior or exterior voids where aluminum powder can infiltrate and accumulate.

2-3.4

Floors shall be hard-surfaced and nonslip, installed with a minimum number of joints in which aluminum powder can collect. The requirements of this section shall also apply to elevated platforms, balconies, floors, or gratings. (*See Appendix B.*)

2-3.5

Roofs of buildings that house dust-producing operations shall be supported on girders or structural members designed to minimize surfaces on which dust can collect. Where such surfaces are unavoidably present, they shall be covered by a smooth concrete, plaster, or noncombustible mastic fillet having a minimum slope of 55 degrees to the horizontal.

2-3.6

Roof decks shall be watertight.

2-3.7*

Explosion venting shall be provided where aluminum powder is processed and handled. Handling does not include storage in closed containers.

2-4 Doors and Windows.

2-4.1

All door and window frames shall be metal.

2-4.2

Each room shall have at least two widely separated exits to exit corridors or to the outside. All doors in interior fire-rated partitions shall be approved self-closing fire doors, installed in accordance with NFPA 80, *Standard for Fire Doors and Fire Windows*. Hardware for emergency exit doors shall conform to requirements of NFPA 80 and of NFPA *101*®, *Life Safety Code*®. (*See Section 5-11 and Chapter 14 of NFPA 101.*)

2-4.3

Emergency exit doors shall be provided from all areas, including balconies and elevated platforms.

2-4.4

Where two buildings are less than 50 ft (15.2 m) apart, only one of the facing walls shall have windows and doors. (*See also Exception to 2-1.2.*)

2-5 Communication Between Buildings.

2-5.1*

Where buildings are separated by not less than 50 ft (15.2 m) or where small units of one major process section communicate through enclosed passageways, such passageways shall be of noncombustible construction and be specifically designed to relieve internal pressure from an explosion and shall be protected by automatic self-closing 3-hour fire doors.

2-5.2

All enclosed passageways shall be provided with adequate means of egress as provided by NFPA *101*, *Life Safety Code*.

2-6 Grounding and Lightning Protection.

2-6.1*

All process equipment and all building steel shall be bonded and grounded in accordance with NFPA 780, *Lightning Protection Code*, and NFPA 70, *National Electrical Code*®.

2-6.2

Lightning rods shall be provided for all boiler stacks and chimneys and for the high points of all buildings.

2-6.3

Power lines shall be adequately protected against lightning. (*See NFPA 780, Lightning Protection Code*.)

2-6.4

A lightning arrestor system shall be provided around or within the building area of such capacity as to fully protect all buildings from lightning.

2-7 Electrical Power.

2-7.1

All electrical equipment and wiring shall be installed in accordance with NFPA 70, *National Electrical Code*.

2-7.1.1 All parts of powder manufacturing buildings shall be considered Class II, Group E locations.

Exception No. 1: Offices and similar areas so occupied and segregated as to be reasonably free from dust and so classed by the authority having jurisdiction.

Exception No. 2: Control equipment meeting the requirements of NFPA 496, Standard for Purged and Pressurized Enclosures for Electrical Equipment.

NOTE: For additional information on classification of dusty locations, see NFPA 497B, *Recommended Practice for the Classification of Class II Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas*.

2-7.1.2 Wet solvent milling areas shall be considered Class I, Group D locations.

Exception No. 1: Offices and similar areas so occupied and segregated as to be reasonably free from solvent vapors and so classed by the authorities having jurisdiction.

Exception No. 2: Control equipment meeting the requirements of NFPA 496, Standard for Purged and Pressurized Enclosures for Electrical Equipment.

NOTE: For additional information on classification of areas containing solvent vapors, see NFPA 497A, *Recommended Practice for Classification of Class I Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas*.

2-7.2

Provisions shall also be made for remote manual cutoff of all electrical power to manufacturing areas from one or more central locations, such as offices, guard's booth, or other appropriate locations.

2-7.3

All manufacturing buildings shall be provided with emergency lighting systems in accordance with Section 5-9 of NFPA *101, Life Safety Code*.

2-7.4

Electrical equipment shall be inspected and cleaned at least once each year or more frequently if conditions warrant.

2-7.5

Flashlights and storage battery lamps shall be listed for the locations in which they are used.

Chapter 3 Machinery and Operations

3-1 General Precautions.

3-1.1

This chapter shall be applied to new and existing facilities.

3-1.2

In powder handling or manufacturing buildings and in the operation of dust-conveying systems, precautions shall be taken to avoid the production of sparks from static electricity, electrical faults, or impact (e.g., iron or steel articles on stones, on each other, or on concrete).

3-1.3

Water leakage in or into any building where it can contact aluminum powder shall be prevented to avoid possible spontaneous heating.

3-1.4*

Frictional heating shall be minimized by the use of lubrication, inspection programs, and maintenance programs and techniques set forth by the equipment manufacturer's recommendation.

3-2 Requirements for Machinery.

3-2.1

All dust-producing machines and conveyors shall be constructed so that escape of dust is minimized.

3-2.2*

All machinery shall be bonded and grounded to minimize accumulation of static electric charge. This requirement shall be applicable to stamp mortars, mills, fans, and conveyors in all areas where dust is produced or handled, finishing and polishing equipment, filters, driers, dust screens, fixed storage bins, and dust collection and transport systems of all types. (*See also 2-6.1*.)

3-2.3*

Ball or roller bearings, properly sealed against dust, shall be used for shafts and high-speed equipment. Where exposed bearings are used, they shall be protected as well as possible to prevent ingress of aluminum dust.

3-2.4

Internal machine clearances shall be maintained to prevent internal rubbing or jamming.

3-2.5

High-strength permanent magnetic separators, pneumatic separators, or screens shall be installed ahead of mills, stamps, or pulverizers wherever there is any possibility that tramp metal or other foreign objects can be introduced into the manufacturing operation.

3-3 Heating of Aluminum Powder Production Buildings.

3-3.1

Heating of buildings shall be permitted by indirect hot air heating systems or by bare pipe heating systems using steam or hot water as the heat transfer medium or listed electric heaters. Indirect hot air shall be permitted if the heating unit is located in a dust-free area adjacent to the room or area where heated air is required.

3-3.2

Fans or blowers used to convey the heated air shall also be located in a dust-free location. The air supply shall be taken from outside or from a dust-free location.

3-3.3

Make-up air for building heating shall have a dew point low enough to ensure that no free moisture can condense at any point where the air is in contact with aluminum dust or powder.

3-3.4

The requirements of 3-3.1, 3-3.2, and 3-3.3 shall not apply to areas where metal is melted for purposes of atomization.

3-4 Start-up Operations.

All the machine processing contact areas shall be thoroughly cleaned and free from water before being charged with metal and placed into operation.

3-5 Charging and Discharging Aluminum Powders.

3-5.1

All in-plant containers shall be conductive and sealed with waterproof covers while in storage or transit.

3-5.2

When charging aluminum powders to machines (or discharging from), the containers shall be positively bonded and grounded by a conducting cable from the container to a suitable ground connection and to the machine.

3-6* Containers for Transport of Aluminum Powder.

Aluminum powder shall be packed into steel drums or other closed conductive containers acceptable to the U.S. Department of Transportation (DOT) or in containers specifically designed for in-plant transfer of aluminum powder. The containers shall be tightly sealed and stored with proper precautions to keep water from contacting the contents.

3-7* Wet Milling of Aluminum Powder.

3-7.1

Where aluminum is milled in the presence of a liquid which is chemically inert with respect to the metal, the milling shall be done in air in a vented mill or in an inerting atmosphere containing sufficient oxygen to oxidize any newly exposed surfaces as they are formed.

3-7.2

Where aluminum is slurried in tanks or processed in blenders or other similar equipment in the presence of a liquid that is chemically inert with respect to the metal, the operation shall be carried out in air or an inerting atmosphere containing sufficient oxygen to oxidize any newly exposed surfaces as they are formed.

3-7.3

The dew point of the atmospheres in 3-7.1 and 3-7.2 shall be maintained substantially below the point where condensation could occur.

3-7.4

Bearings of wet mills shall be grounded across the lubricating film by use of current collector brushes.

3-7.5

Ventilation, forced or natural, in accordance with NFPA 30, *Flammable and Combustible Liquids Code*, shall be maintained in areas where solvents are handled.

3-7.6

Solvent or slurry pumps shall be installed with proper controls to ensure that they are shut down when they run dry.

3-7.7

All electrical equipment shall be installed in accordance with appropriate provisions of NFPA 70, *National Electrical Code*.

Chapter 4 In-Plant Conveying of Aluminum Powder

4-1 Portable Containers.

4-1.1

Transfer of powders in-plant shall be done in suitable conductive containers as described in Chapter 3.

4-1.2

Powered forklift trucks shall be selected in accordance with NFPA 505, *Fire Safety Standard for Powered Industrial Trucks Including Type Designations, Areas of Use, Maintenance, and Operation*.

4-1.3

Containers approved by the U.S. Department of Transportation (DOT) for shipment of aluminum powders shall be permitted to be used.

4-1.4

All wheeled containers, hand trucks, and lift trucks shall have nonsparking, static conductive tires and wheels that have been bonded through or around the lubricating film in the bearings or shall have grounding straps.

4-2 Pneumatic Conveying.

4-2.1

Conveyor ducts shall be fabricated of nonferrous minimum-sparking metal or of nonmagnetic minimum-sparking stainless steel.

4-2.2*

Ducts shall be electrically bonded and grounded to minimize accumulation of static electric charge.

4-2.3

Plastics or other nonconductive ducts or duct liners shall not be used.

4-2.4*

If the conveying gas is air, the aluminum powder-to-air ratio throughout the conveying system shall be held below 50 percent of the lower flammable limit (LFL) of the aluminum powder at normal operating conditions.

4-2.4.1* Operation near or above the LFL shall be permitted if an inert gas conveying system is used. See NFPA 69, *Standard on Explosion Prevention Systems*.

4-2.4.2* The inert gas used shall be based on such gases as nitrogen, argon, helium, or flue gas, and shall have an oxygen concentration determined by test to be appropriate to the inerting gas and the particle size of the aluminum powder.

Exception: Where the product is never exposed to air, the oxygen content can be zero.

4-2.4.3 The inert gas shall have a dew point such that no free moisture can condense or accumulate at any point in the system.

4-2.4.4 The inert gas stream shall be continuously monitored for oxygen content and shall be arranged to sound an alarm if the oxygen content is not within a prescribed range.

4-2.5*

Where the conveying duct is exposed to weather or moisture, it shall be moisturetight.

4-2.6

A minimum conveying velocity of 4500 ft/min (1364 m/min) shall be maintained throughout the conveying system to prevent the accumulation of dust at any point and to pick up any dust or powder that can drop out during an unscheduled system stoppage.

4-2.7

If the conveying gas is inducted into the system in a relatively warm environment and the ducts and collectors are relatively cold, the ducts and the collectors shall be either insulated or provided with heating so that the gas temperature does not fall below the dew point, causing condensation.

4-2.8*

If the dust is collected in a liquid, such as in a spray tower, any liquid used shall not have a flash point below 100°F (37.8°C) and shall be nonreactive with metal dust or reactive at a controlled rate under favorable operating conditions. The liquid remaining in or on the product shall be compatible with subsequent processing requirements.

4-3 Ductwork for Conveying Systems.

4-3.1*

Explosion vents, openings protected by antiflashback swing valves, or rupture diaphragms, shall be provided on ductwork. Relief shall be to a safe location outside of the building.

4-3.2

Wherever damage to other property or injury to personnel can result from the rupture of the ductwork, or where explosion relief vents cannot provide sufficient pressure relief, the ductwork shall be designed to withstand a suddenly applied internal pressure of at least 100 psig (690 kPa gauge).

Exception: If a portion of the ductwork is so located that no damage to property or injury to personnel will result from its bursting, that portion shall be permitted to be of light construction so as to intentionally fail, thereby acting as an auxiliary explosion vent for the system.

4-4 Fan and Blower Construction and Arrangement.

4-4.1

Blades and housings of fans used to move air or inert gas in conveying ducts shall be constructed of conductive, nonsparking metal such as bronze, nonmagnetic stainless steel, or aluminum.

4-4.2

Wherever practical, the design shall not allow the transported dust or powder to pass through the fan before entering the final collector.

4-4.3

Personnel shall not be permitted within 50 ft (15.2 m) of the fan or blower while it is operating. No maintenance shall be performed on the fan until it is shut down.

Exception: If personnel approach the fan or blower while it is operating, such as for a pressure test, it shall be done under the direct supervision of competent technical personnel and with the knowledge and approval of operating management and with the flow of aluminum powder shut off.

4-4.4*

Fans or blowers shall be located outside of all manufacturing buildings and so located that entrance of dust from the fan exhaust into the building shall be minimized.

4-4.5*

Fans or blowers shall be equipped with ball or roller bearings. Bearings shall be equipped with suitable temperature-indicating devices and shall be arranged to sound an alarm in case of over-temperature.

4-4.6

Fans or blowers shall be electrically interlocked with powder-producing machinery so that the machines are shut down if the fan stops.

Chapter 5 Dust and Powder Collection

5-1* Collectors.

5-1.1

Dry-type collectors shall be located outside, in a safe location, and shall be provided with suitable barriers or other means for protection of personnel.

5-1.2

Collectors shall be constructed of nonferrous, minimum-sparking metal or of nonmagnetic, minimum-sparking stainless steel.

5-1.3

Ductwork shall comply with the provisions of Section 4-3.

5-1.4*

The entire collection system, including the collector, shall be completely bonded and grounded to minimize accumulation of static electric charge.

5-2 Fans and Other Air-Moving Equipment.

5-2.1

Fans and other equipment for moving air shall be located so the fan is on the clean air side of the collector.

5-2.2

Fans shall be provided with ball or roller bearings.

5-3 High Temperature Warning.

5-3.1

Cyclone or other dry-type collectors shall be equipped with suitable instruments for recording the surface temperature. An over-temperature alarm or warning device shall be included and the limit setting shall be below the maximum service temperature of the filter medium or 90°F (32°C) below the ignition temperature of the powder cloud, whichever is lower.

5-3.2

Alarms and actuating equipment shall be suitable for use in Class II, Group E locations, as specified in NFPA 70, *National Electrical Code*, or shall be located in a nonhazardous location.

NOTE: See NFPA 497B, *Recommended Practice for the Classification of Class II Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas.*

5-3.3

All such instruments shall give audible and visual alarm at normally attended locations.

5-4* Collector Filter Medium.

Collector filter medium made from synthetic fabrics that accumulate high static electric charges shall not be used. Replacement filter media shall be in accordance with this criteria.

Chapter 6 Prevention of Fugitive Dust Accumulations

6-1 General.

6-1.1

This chapter shall apply to new and existing facilities.

6-1.2

Dust shall not be permitted to accumulate. Spills shall be removed at once, using conductive, nonsparking scoops and soft brooms or brushes having natural fiber bristles.

6-1.2.1 Final cleanup shall be permitted to be accomplished using a vacuum cleaning system designed in accordance with Section 6-2.

6-1.2.2 Compressed air blowdown shall not be permitted.

Exception: In certain areas impossible to clean otherwise, compressed air blowdown shall be done under carefully controlled conditions with all potential ignition sources prohibited in or near the area and the equipment shut down.

6-1.3

The use of water for cleaning shall not be allowed in manufacturing areas unless the following requirements are met:

(a) It has been determined by competent technical personnel that the use of water will be the safest method of cleaning in the shortest exposure time.

(b) Operating management has full knowledge of and has granted approval of its use.

(c) Adequate ventilation, either natural or forced, is available to maintain the hydrogen concentration safely below the lower flammable limit (LFL).

(d) Complete drainage of all water and powder to a safe, remote area is available.

6-2* Vacuum Cleaning Systems.

6-2.1

Vacuum cleaning systems shall only be used for removal of dust accumulations too small or too dispersed to be thoroughly removed by hand-brushing.

6-2.2*

Vacuum cleaning systems shall be effectively grounded and bonded to minimize accumulation of static electric charge.

6-2.3

Where aluminum dust is present, the fixed vacuum cleaning system's electrical equipment shall be suitable for Class II, Group E locations.

6-2.4

Vacuum cleaner hoses shall be conductive and nozzles or fittings shall be made of conductive, nonsparking material.

6-2.5

Dust picked up by the vacuum cleaning system shall be discharged into a suitable receptacle or collector located outside the building.

6-2.6

Portable vacuum cleaners shall be used only if listed for use in the area in which they are to be used or shall be nonelectrically powered.

6-3 Cleaning Frequency.

6-3.1

Supervisors shall be alert to prevent the accumulation of excessive dust on any portions of buildings or machinery not regularly cleaned in daily operations.

6-3.2

Regular periodic cleaning of buildings and machinery, with all machinery idle and power off, shall be carried out as frequently as conditions warrant.

Chapter 7* Fire Fighting Procedures

7-1 Dry Aluminum Powders.

7-1.1

Sections 7-1 and 7-2 shall apply to new and existing facilities.

7-1.2

An incipient fire shall be ringed with a dam of dry sand, dry inert granular material, or a Class D extinguishing agent. Extreme care shall be exercised during application to avoid any disturbance of the aluminum powder, which could cause a dust cloud. The dry extinguishing material shall be stored in such a manner that it remains clean and dry.

7-1.3

The dry material shall be carefully applied with a nonsparking metal scoop or shovel or applied from an extinguisher equipped with a low-velocity nozzle.

7-1.4

Care shall be exercised to eliminate drafts by shutting off fans and machinery and by closing doors and windows.

7-1.5

Areas where dry aluminum powders are produced or handled shall not have fire extinguishers rated for Class A, B, or C fires.

Exception: Where Class A, B, or C fire hazards are in the powder area, extinguishers suitable for use on such fires shall be permitted, provided they are marked "Not for Use on Aluminum Powder Fires."

7-2* Solvent-Wetted Powders.

7-2.1

A fire occurring while the aluminum powder is in slurry form shall be permitted to be fought using Class B extinguishing agents.

Exception: Halogenated extinguishing agents shall not be used.

7-2.2

A fire occurring in semi-wet material or filter-cake shall be fought using suitable Class B extinguishing agent.

7-2.3*

Where carbon dioxide is used to extinguish fires involving solvent-wetted aluminum, the residual material shall be immediately covered with dry sand or with other suitable Class D extinguishing agent and the entire mass shall be allowed to cool until it reaches ambient temperature. When the material has cooled and it has been determined that there are no hot spots, the covered material shall be carefully removed for disposal. It shall be handled in small quantities in covered containers, preferably not more than 3 gal (11.5 L) each in 5-gal (19.2 L) containers.

7-2.4

Manual water application shall only be used on a solvent-metal powder fire as a last resort, when other methods of control have failed and the fire shows evidence of going out of control. Only low-velocity spray or fog nozzles shall be used. Extreme care shall be exercised to avoid creating a dust cloud. Once water is used, its use shall be continued until the fire is extinguished or until the area becomes untenable.

7-2.4.1 After extinguishment, the area shall be immediately cleaned of all wetted powder, paste, or slurry.

7-2.4.2 Adequate ventilation shall be provided during cleanup to avoid concentrations of hydrogen from the exothermic reaction of the aluminum with water.

7-2.4.3 Suitable drainage provisions to a safe area away from manufacturing buildings shall be provided.

7-3 Automatic Sprinkler Protection.

7-3.1

Automatic sprinkler protection shall not be permitted in areas where dry aluminum powders are produced or handled.

7-3.2

Automatic sprinkler protection shall be permitted in areas where solvents are stored or used (*see NFPA 30, Flammable and Combustible Liquids Code*); aluminum paste is produced or handled; or dry aluminum powder is stored in sealed containers.

7-3.2.1 The decision of whether or not to use automatic sprinkler protection shall be based on the need to minimize the damage to property and risk to life resulting from fires and explosions involving both wetted and dry aluminum powders.

7-3.2.2 The special hazards associated with aluminum powder in contact with water shall be considered in the selection, design, and installation of automatic sprinkler systems.

7-3.2.3 Automatic sprinkler systems shall be designed and installed in accordance with NFPA 13, *Standard for the Installation of Sprinkler Systems*.

7-3.2.4 Special attention shall be given to employee training and organizational planning to ensure safe evacuation of the sprinkler protected area, in case of fire.

7-4 Fire Fighting Organization.

7-4.1

Only trained personnel shall be permitted to engage in fire control activity. All others shall be evacuated from the area. Training shall emphasize the different types of fires anticipated and the appropriate agents and techniques to be used.

7-4.2

Fire fighting personnel shall be given regular and consistent training in the extinguishment of test fires set in a safe location away from manufacturing buildings. Training shall include all possible contingencies.

7-4.3*

If professional or volunteer fire fighters are admitted onto the property in the event of a fire emergency, their activity shall be directed by the on-site ranking officer of the trained plant fire fighters.

Chapter 8 Safety Requirements

8-1* General.

This chapter shall apply to new and existing facilities.

8-2 Guidelines.

8-2.1

Training programs shall be instituted to properly inform employees about the hazards involved in the manufacture of aluminum powder, paste, or granules, or the manufacture of atomized aluminum powder. As a minimum, the following areas shall be addressed:

8-2.1.1 Dust Explosion Hazards.

8-2.1.2 Control of Ignition Sources.

8-2.1.2.1* No smoking, open flames, electric or gas cutting or welding equipment, or spark-producing operations shall be permitted in the section of the building where aluminum dust is produced or handled. This type of work shall be allowed only in the areas where all machinery is shut down and the area is thoroughly cleaned and inspected to ensure the removal of all accumulations of aluminum dust. Accepted lockout/tagout procedures shall be followed for the shutdown of machinery.

8-2.1.2.2 Smoking materials, matches, and lighters shall not be carried or used by employees or visitors about the premises adjacent to or within any building in which aluminum powder is produced, handled, or loaded for shipment.

8-2.1.2.3 Propellant-actuated tools shall not be used in areas where a dust explosion can occur unless all machinery in the area is shut down and the area and machinery are properly cleaned.

8-2.1.2.4* Nonsparking tools shall be used when making repairs or adjustments on or around any machinery or apparatus where aluminum dust is present.

8-2.1.3 Housekeeping.

8-2.1.3.1 The work area shall be maintained as clean, orderly, and sanitary as working conditions allow.

8-2.1.3.2 Brooms and brushes used for cleaning shall be of a natural bristle type. Synthetic bristles shall not be used. Scoops, dustpans, etc., used for collecting sweepings shall be made of nonsparking, conductive material.

8-2.1.3.3 Dry powder dust sweepings shall not be returned to any machine for processing.

8-2.1.4 Fire Protection Equipment and Practices. (*See Chapter 7*.)

8-2.1.5 Personal Protective Equipment.

8-2.1.5.1 Outer clothing shall be clean, flame resistant, and non-static generating and shall be designed to be easily removable. Tightly woven, smooth fabrics treated with a flame-retardant chemical, and from which dust can readily be brushed, shall be used, if necessary. Woolen, silk, or synthetic fabrics that can accumulate high static electric charges shall not be used.

8-2.1.5.2 Work clothing shall have no external pockets unless covered with a flap fitted with a closure of some sort. Trousers shall not have cuffs.

8-2.1.5.3* Safety shoes shall be conductive, have no exposed metal, and shall be appropriate for the type of operation taking place.

8-2.2*

Emergency procedures to be followed in case of fire or explosion shall be established. All employees shall be trained in these procedures.

8-2.3

Procedures shall be established for the recognition and control of employee exposure to air contaminants.

8-2.4

A thorough inspection of the operating area shall take place on an "as needed" basis to help ensure that the equipment is in good condition and that proper work practices are being followed. This inspection shall be conducted at least quarterly, but shall be permitted to be done more often.

8-2.4.1 It shall be conducted by a person(s) knowledgeable in the proper practices, who shall record the findings and recommendations.

8-2.4.2 Regular and periodic maintenance checks and calibration on equipment critical to employee safety and plant operation shall be performed.

8-2.5

Deluge showers shall be installed at strategic locations immediately outside critical working areas to quickly douse clothing fires.

8-2.6 Fire Blankets.

Fire blankets shall be provided throughout the plant area.

Chapter 9 Referenced Publications

9-1

The following documents or portions thereof are referenced within this standard and shall be

considered part of the requirements of this document. The edition indicated for each reference is the current edition as of the date of the NFPA issuance of this document.

9-1.1 NFPA Publications.

National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.

NFPA 13, *Standard for the Installation of Sprinkler Systems*, 1991 edition.

NFPA 30, *Flammable and Combustible Liquids Code*, 1993 edition.

NFPA 69, *Standard on Explosion Prevention Systems*, 1992 edition.

NFPA 70, *National Electrical Code*, 1993 edition.

NFPA 80, *Standard for Fire Doors and Fire Windows*, 1992 edition.

NFPA *101*, *Life Safety Code*, 1991 edition.

NFPA 496, *Standard for Purged and Pressurized Enclosures for Electrical Equipment*, 1993 edition.

NFPA 505, *Fire Safety Standard for Powered Industrial Trucks Including Type Designations, Areas of Use, Maintenance, and Operation*, 1992 edition.

NFPA 780, *Lightning Protection Code*, 1992 edition.

Appendix A Explanatory Material

This Appendix is not a part of the requirements of this NFPA document but is included for information purposes only.

A-1-1.1

Certain “nondusting” grades of aluminum flake powder are being produced. Although they exhibit less tendency to be dispersed into a dust cloud, the same precautions described in this standard should be observed.

A-1-5 Combustible Aluminum Dust.

Any time a combustible dust is processed or handled, a potential for explosion exists. The degree of explosion hazard will vary depending on the type of combustible dust and processing methods used.

A dust explosion has three requirements, all of which must be met:

(a) The dust must be combustible.

(b) The dust particles must form a cloud at or exceeding the lower flammable limit.

(c) A source of ignition must be present.

Evaluation of a combustible dust explosion hazard and the prevention techniques employed should be determined by means of actual test data. All combustible dusts that may produce a dust explosion should be tested so as to determine the following data:

(a) Particle size distribution.

(b) Moisture content as received and dried.

(c) Minimum dust concentration to ignite.

(d) Minimum energy required for ignition (joules).

(e) Maximum rate of pressure rise at various concentrations.

(f) Layer ignition temperature.

(g) Maximum explosion pressure, at optimum concentration.

Optional Testing.

(a) Dust cloud ignition temperature.

(b) Maximum permissible oxygen content to prevent ignition.

(c) Electrical resistivity measurement.

A-2-3.7

For information on deflagration venting, see NFPA 68, *Guide for Venting of Deflagrations*.

A-2-5.1

For information on deflagration venting, see NFPA 68, *Guide for Venting of Deflagrations*.

A-2-6.1

For information on static electricity, see NFPA 77, *Recommended Practice on Static Electricity*.

A-3-1.4

Temperature-sensing elements connected to alarms or machine stop switches may be employed for locations where overheating of bearings or other elements may be anticipated.

A-3-2.2

See NFPA 77, *Recommended Practice on Static Electricity*, for information on the subject.t

A-3-2.3

Journal bearings should not be used because of the difficulty of maintaining proper lubrication to prevent overheating. Outboard bearings are used where practical because it is easier to check for overheating. In those instances where dust tends to penetrate bearings a continuous flow of inert gas ($1^1/_2$ to 5 percent oxygen) can be employed to pressurize the bearings and seals.

A-3-6

Open bin storage is not desirable. Storage bins can be sealed and they can be purged with inert gas prior to filling. Once filled, the bins can be maintained inert by a suitable gas as detailed in 4-2.4.2.

A-3-7

When aluminum is milled in the presence of a liquid that is chemically inert with respect to the metal, the air-dust explosion hazard is eliminated. When the resulting product is subsequently exposed to air, any unoxidized surfaces produced during milling will react and may generate enough heat to cause ignition. To prevent this, it is imperative that a controlled amount of oxygen be present in the milling operation and in slurries ahead of filters and blenders, so that new surfaces are oxidized as they are formed. The addition of a milling agent, such as stearic acid, does not eliminate the need for this added oxygen.

A-4-2.2

See NFPA 77, *Recommended Practice on Static Electricity*.

A-4-2.4

These minimum explosive concentrations are published in U.S. Bureau of Mines, RI 6516, "*Explosibility of Metal Powders*." Although the aluminum powder-air suspension may be held below 50 percent of the LFL in the conveying system, the suspension will necessarily pass through the flammable range in the collector at the end of the system unless the dust is collected in liquid, such as in a spray tower. Also, the powder in the conveying line from the atomizer to the collector will, of necessity, approach the lower flammable limit.

A-4-2.4.1 Aluminum and aluminum alloy powders are produced by various means. These processes, as well as certain finishing and transporting operations, tend to expose a continuously increasing area of new metal surface. Most metals immediately undergo a surface reaction with available atmospheric oxygen which forms a protective coating of metal oxide that serves as an impervious layer to inhibit further oxidation. This reaction is exothermic. If a fine or thin lightweight particle having a large surface area of "new" metal is suddenly exposed to the atmosphere, sufficient heat will be generated to raise its temperature to the ignition point.

Completely inert gas generally cannot be used as an inerting medium since the aluminum powder would eventually, at some point in the process, be exposed to the atmosphere, at which time the unreacted surfaces would be oxidized; enough heat would be produced to initiate either a fire or an explosion. To provide maximum safety, a means for the controlled oxidation of newly exposed surfaces is provided by regulating the oxygen concentration in the inert gas. The mixture serves to control the rate of oxidation, while materially reducing the fire and explosion hazard.

A completely inert gas can be used if the powder so produced will not be exposed to air.

A-4-2.4.2 Oxygen limits of 3 to 5 percent have been maintained in aluminum powder systems using a controlled flue gas. Other limits are applicable where other inert gases are used. Refer to U.S. Bureau of Mines, RI 3722, "*Inflammability and Explosibility of Metal Powders*."

A-4-2.5

Any moisture entering the system can react with the aluminum powder, generating heat and hydrogen. Hydrogen is extremely flammable and very easy to ignite. It must not be trapped in nonventilated areas of buildings, equipment, or enclosures.

A-4-2.8

Such wet collection is not always possible or desirable.

A-4-3.1

For information on explosion vents, see NFPA 68, *Guide for Venting of Deflagrations*.

A-4-4.4

Ultimately, all fans or blowers in dust collector systems accumulate sufficient powder to become a potential explosion hazard.

A-4-4.5

Fans or blowers may also be provided with vibration-indicating devices, arranged to sound an alarm or to provide shutdown, or both, in the event of blade or rotor imbalance, or bearing or drive problems.

A-5-1

A high-efficiency cyclone-type collector presents less hazard than a bag- or media-type collector and, except for extremely fine powders, will usually operate with fairly high collection efficiency. Where cyclones are used, the exhaust fan discharges to atmosphere away from other operations. It should be recognized that there will be some instances in which a centrifugal-type collector may be followed by a fabric or bag- or media-type collector or by a scrubber-type collector where particulate emissions are kept at a low level. The hazards of each collector should be recognized and protected against. In each instance, the fan will be the last element downstream in the system. Because of the extreme hazard involved with a bag- or media-type collector, consideration should be given to a multiple-series cyclone with a liquid final stage.

Industry experience has clearly demonstrated that an eventual explosion can be expected where a bag- or media-type collector is used to collect aluminum fines. Seldom, if ever, can the source of ignition be positively identified. In those unusual instances when it becomes necessary to collect very small fines for a specific commercial product, it is customary for the producer to employ a bag- or media-type collector. With the knowledge that strong explosive potential is present, the producer will locate the bag- or media-type collector a safe distance from buildings and personnel.

If a bag- or media-type collector is used, the shaking system or dust removal system can be such as to minimize sparking due to frictional contact or impact. Pneumatic or pulse-type shaking is more desirable because no mechanical moving parts are involved in the dusty atmosphere. If the bags are provided with grounding wires, they can be positively grounded through a low-resistance path to ground. Where bags are used, it is customary that the baghouse be protected by an alarm to indicate excessive pressure drop across the bags. An excess air temperature alarm is also frequently employed. A bag- or media-type collector is customarily located at least 50 ft (15.2 m) from any other building or operation. It is not customary to permit personnel to be within 50 ft (15.2 m) of the collector during operation or when shaking bags. Explosion vents are usually built into the system, as described in NFPA 68, *Guide for Venting of Deflagrations*. Care is customarily exercised in locating the vents because of the possibility of blast damage to personnel or adjacent structures.

A-5-1.4

For information on precautions for static electricity, see NFPA 77, *Recommended Practice on Static Electricity*.

A-5-4

Some collector bags or other types of media or screens have fine, noninsulated wire enmeshed into or woven with the cloth or otherwise fastened to it. These are always securely grounded. It should be pointed out that this is not a positive guarantee of static charge removal because there is no dependable force to cause the charges to move across the nonconducting area of the fabric to the grounded wires. Often, a substantial potential difference can be measured. Also, it is possible that a wire in the cloth may break in such a way that it is no longer grounded. Such a wire serves as a capacitor and may store a static charge.

A-6-2

Permanently installed vacuum cleaning systems provide the maximum safety because the dust collecting device and the exhaust blower can be located in a safe location outside the dust-producing area. The dust collector should be located outside the building, preferably more than 50 ft (15.2 m) away. If the collector is located closer than 50 ft (15.2 m), it is usually surrounded by a strong steel shield, cylindrical in shape and open at the top, or closed with a light, unfastened cover. The shield is closed at the bottom and designed to withstand a blast pressure of 200 psig (1380 kPa gauge). Such a protective barricade will direct an explosion harmlessly upward and will protect both property and personnel. All suction lines should be provided with explosion vents and anti-flashback valves.

A-6-2.2

See NFPA 77, *Recommended Practice on Static Electricity*.

A-7

Since it is almost impossible to extinguish a massive fire in dry aluminum powder, the fire problem resolves itself into the control of fires in the incipient stage. The requirements of Section 7-1 should be followed if the fire is to be controlled quickly. This is especially true with regard to the application of the extinguishing material, as even a minor dust cloud can explode violently.

A properly ringed fire will develop a hard crust of metal oxide, which will ultimately exclude enough oxygen to cause self-extinguishment. It is customary practice, after dispensing the extinguishing material, to leave the area, closing all doors leading to the area and sealing them with sand. The area should not be re-entered until combustion has stopped and the material has cooled.

A-7-2

Milling of aluminum with combustible solvents is practiced in the manufacture of aluminum flake used in pigments and powders. The material is handled as a slurry during processing. Some of the product is marketed as a paste; other portions are filtered, dried, sometimes polished, and sold as dry flake powder. The solvents employed are generally moderately high flash-point naphthas. A fire in an aluminum powder slurry is primarily a solvent fire and can be fought using Class B extinguishing agents, except for halogenated extinguishing agents.

Major producers usually employ fixed extinguishing systems of carbon dioxide or foam in this area. Some Class B portable extinguishers are provided also. Obviously, judgment should be used in determining whether Class B extinguishing agents can be safely used. If the extinguishing agent is carefully applied, it will be very evident if it accelerates the fire. If it does, its use should be discontinued and a dry inert granular material used. A fire in filter cake, a solvent-wetted but semi-dry material containing aluminum, may be a solvent fire or it may at some point exhibit the characteristic of a powder fire, at which time it should be treated as such. If the aluminum metal has ignited, it may continue to burn under a crust without flames.

A-7-2.3

Reignition may occur due to high localized heat or spontaneous heating. To avoid reignition, the residual material should be immediately smothered.

A-7-4.3

It is recommended that a practice fire drill be conducted once each year to familiarize local fire department personnel with the proper methods of fighting Class D fires.

A-8-1

Employees' health and safety in operations depend on the recognition of actual or potential hazards, controlling or eliminating these hazards, and training employees to work safely.

A-8-2.1.2.1 Attention is called to the hazardous conditions that may exist both inside and outside the plant if cutting torches are used to dismantle dust collectors or powder-producing machinery before all dust accumulations have been removed.

It is a commonly recognized practice that operators of cutting or welding torches be required to obtain a written permit from the safety or fire protection officer of the plant before using their equipment under any condition around aluminum powder plants.

A-8-2.1.2.4 Under certain circumstances, such as impact with rusted iron or steel, aluminum cannot safely be considered to be nonsparking since a minor thermite reaction can be initiated. For details, refer to "Aluminum and the Gas Ignition Risk," by H. S. Eisner and "Fire Hazards in Chemical Plants from Friction Sparks Involving the Thermite Reaction." (*See Appendix C.*)

A-8-2.1.5.3 Safety shoes meeting the following guidelines should be worn by all operating personnel except those persons who are required to work on electrical circuits or equipment.

(a) Soles should be resistant to embedding particles and to petroleum solvents, if used.

(b) Soles and heels should be attached by sewing or pegging.

(c) Nails, metal cleats, or metal plates should not be used.

(d) Safety toe caps should be completely covered with a scuff-resistant material.

(e) Soles and heels should be static conductive.

A-8-2.2 Employee Training.

(a) All employees should be carefully and thoroughly instructed by their supervisors regarding the hazards of their working environment and their behavior and procedures in case of fire or explosion.

(b) All employees should be shown the location of electrical switches and alarms, first-aid equipment, safety equipment, and fire extinguishing equipment.

(c) All employees should be taught the permissible methods for fighting incipient fires in pastes and for isolating aluminum fires.

(d) The hazards involved in causing dust clouds and the danger of applying liquids onto an incipient fire should be explained.

(e) Strict discipline and scrupulous housekeeping should be maintained at all times.

(f) Attention should be given to employee training and organizational planning to ensure safe and proper evacuation of the area.

Appendix B Electrically Conductive Floors

This Appendix is not a part of the requirements of this NFPA document, but is included for *information purposes only*.

B-1 General.

B-1.1

Electrically conductive flooring is often employed in aluminum powder plants, although it is recognized that it is difficult to maintain the conductivity of the floor over a period of time using currently available materials. Careful examination of the details of this standard will disclose the logic of the use of conductive flooring materials.

B-1.2

The surface of a conductive floor will provide a path of moderate electrical conductivity between all persons and portable equipment making contact with the floor, thus preventing the accumulation of dangerous electrostatic charges.

B-1.3

The maximum resistance of a conductive floor is usually less than 1,000,000 ohms, as measured between two electrodes placed three feet apart at any two points on the floor. The minimum resistance is usually greater than 25,000 ohms, as measured between a ground connection and an electrode placed at any location on the floor. This minimum resistance value provides protection for personnel against electrical shocks. Resistance values are checked at regular intervals, usually once each month.

B-2 Testing for Minimum and Maximum Resistance.

The following equipment and procedures are accepted practice.

B-2.1

Each electrode will weigh 5 lbs (2.27 kg) and will have a dry, flat, circular contact area 2.5 in. (6.4 cm) in diameter. The electrode will consist of a surface of aluminum foil 0.0005 in. (0.013 mm) to 0.001 in. (0.025 mm) thick, backed by a layer of rubber 0.25 in. (6.35 mm) thick and measuring 40 to 60 durometer hardness, as determined by a Shore Type A Durometer or equivalent, per ASTM D2240, *Standard Test Method for Rubber Property — Durometer Hardness*.

B-2.2

Resistance may be measured with a suitably calibrated ohmmeter that can operate on a nominal open circuit output voltage of 500 volts dc and a short-circuit current of 2.5 to 10.0 m amp.

B-2.3

Measurements may be made at five or more locations in each room and the results averaged.

B-2.4

For compliance with the maximum resistance limit, the average of all measurements should be less than 1,000,000 ohms.

B-2.5

For compliance with the minimum resistance limit, no individual measurement should be less than 10,000 ohms and the average of not less than five measurements should be greater than 25,000 ohms.

B-2.6

Where resistance to ground is measured, two measurements are customarily made at each location, with the test leads interchanged at the instruments between the two measurements. The average of the two measurements is taken as the resistance to ground at that location. Measurements are customarily taken with the electrode or electrodes more than 3 ft (0.9 m) from any ground connection or grounded object resting on the floor. If resistance changes appreciably with time during a measurement, the value observed after the voltage has been applied for about five minutes can be considered the measured value.

Appendix C Referenced Publications

C-1

The following documents or portions thereof are referenced within this standard for informational purposes only and thus are not considered part of the requirements of this document. The edition indicated for each reference is the current edition as of the date of the NFPA issuance of this document.

C-1.1 NFPA Publications.

National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.

NFPA 30, *Flammable and Combustible Liquids Code*, 1993 edition.

NFPA 65, *Standard for the Processing and Finishing of Aluminum*, 1993 edition.

NFPA 68, *Guide for Venting of Deflagrations*, 1988 edition.

NFPA 69, *Standard on Explosion Prevention Systems*, 1992 edition.

NFPA 77, *Recommended Practice on Static Electricity*, 1993 edition.

NFPA 497A, *Recommended Practice for Classification of Class I Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas*, 1992 edition.

NFPA 497B, *Recommended Practice for the Classification of Class II Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas*, 1991 edition.

NFPA 780, *Lightning Protection Code*, 1992 edition.

C-1.2 ASTM Publication.

American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA, 19103-1187.

ASTM D2240, *Standard Test Method for Rubber Property — Durometer Hardness*, 1991 edition.

C-1.3 U.S. Bureau of Mines Publications.

U.S. Bureau of Mines, Cochrans Mill Road, Pittsburgh, PA, 15236-0070.

RI 3722, "*Inflammability and Explosibility of Metal Powders*," I. Hartmann, J. Nagy, and H. R. Brown, 1943.

RI 6516, "*Explosibility of Metal Powders*," M. Jacobsen, A. R. Cooper, and J. Nagy, 1964.

C-1.4 Other Publications.

Eisner, H. S., "Aluminum and the Gas Ignition Risk," *The Engineer*, London, February 17, 1967.

Gibson et. al., "*Fire Hazards in Chemical Plants from Friction Sparks Involving the Thermite Reaction*," Industrial Chemists Engineering Symposium Series, No. 25, London, 1968.

NFPA 654

1994 Edition

Standard for the Prevention of Fire and Dust Explosions in the

Chemical, Dye, Pharmaceutical, and Plastics Industries

1994 Edition

This edition of NFPA 654, *Standard for the Prevention of Fire and Dust Explosions in the Chemical, Dye, Pharmaceutical, and Plastics Industries*, was prepared by the Technical Committee on Fundamentals of Dust Explosion Prevention and Control and acted on by the National Fire Protection Association, Inc., at its Annual Meeting held May 16–18, 1994, in San Francisco, CA. It was issued by the Standards Council on July 14, 1994, with an effective date of August 5, 1994, and supersedes all previous editions.

The 1994 edition of this document has been approved by the American National Standards Institute.

Changes other than editorial are indicated by a vertical rule in the margin of the pages on which they appear. These lines are included as an aid to the user in identifying changes from the previous edition.

Origin and Development of NFPA 654

NFPA 654 was initiated by the Committee on Dust Explosion Hazards in 1943 and originally applied only to the prevention of dust explosions in the plastics industry. As such, it was tentatively adopted in 1944 and officially adopted in 1945. Amendments were adopted in 1946, 1959, 1963, and 1970. The 1970 edition was reconfirmed in 1975.

In 1976, responsibility for NFPA 654 was transferred to the Technical Committee on Fundamentals of Dust Explosion Prevention and Control. The Committee, in completely revising the document, also expanded its scope to include chemical, dye, and pharmaceutical dusts, since the fire and explosion hazards of these dusts are generally the same as for plastic dusts.

The 1982 edition of this standard consisted of a complete rewrite of the 1975 edition. Due to limited technological changes in this area since 1982, the Committee voted to reconfirm the text as it appears in the 1982 version. Editorial corrections and changes to allow the document to adhere more closely to the NFPA *Manual of Style* were incorporated into the 1988 edition.

For the 1994 edition of NFPA 654, the standard was partially revised to improve its usability, adoptability, and enforceability; to update out-dated terminology; and to add the NFPA language for equivalency and retroactivity. In addition, the Technical Committee on Fundamentals of Dust Explosion Prevention and Control added new technologies for explosion prevention to be consistent with the 1992 edition of NFPA 69, *Standard on Explosion Prevention Systems*. The Committee also clarified the requirements relating to controlling hazardous accumulations of process dust.

Technical Committee on Fundamentals of Dust Explosion Prevention and Control

Robert W. Nelson, *Chair*
Industrial Risk Insurers, CT

John M. Cholin, J. M. Cholin Consultants Inc., NJ

C. James Dahn, Safety Consulting Engr. Inc., IL

David C. Kirby, Union Carbide Corp., WV

James E. Maness, Bunge Corp., AR
Rep. Grain Elevator & Processing Society

Michael E. Mowrer, HSB Professional Loss Control Inc., TN

Gary A. Page, American Cyanamid Co., NJ

James L. Roberts, Fluor Daniel, Inc., SC

R. F. Schwab, Allied-Signal Inc., NJ
Rep. Society of the Plastics Industry Inc.

Jeffery W. Sutton, Liberty Mutual Insurance Cos., IL
Rep. The Alliance of American Insurers

John Valiulis, Factory Mutual Research Corp., MA

Harold H. Weber, The Sulphur Inst., DC
(Vote limited to NFPA 655)

Alternates

Committee Scope: This Committee shall have primary responsibility for documents that are generally applicable to all dusts concerning the fundamentals of dust explosion prevention. This Technical Committee also shall be responsible for documents on the prevention, control, and extinguishment of fires and explosions in dust collection equipment and in pneumatic conveying equipment.

NFPA 654
Standard for the
Prevention of Fire and Dust Explosions in the Chemical, Dye, Pharmaceutical and Plastics Industries

1994 Edition

NOTICE: An asterisk (*) following the number or letter designating a paragraph indicates explanatory material on that paragraph in Appendix A.
Information on referenced publications can be found in Chapter 8 and Appendix B.

Chapter 1 General

1-1 Scope.

1-1.1

This standard shall apply to all phases of the manufacture and processing of industrial dusts including, but not limited to, chemicals, dyes, pharmaceuticals and plastics where a fire or explosion hazard might exist due to the presence of combustible dusts.

1-1.2

This standard shall not apply to materials covered by the following:

NFPA 61A, *Standard for the Prevention of Fire and Dust Explosions in Facilities Manufacturing and Handling Starch*

NFPA 61B, *Standard for the Prevention of Fires and Explosions in Grain Elevators and*

Facilities Handling Bulk Raw Agricultural Commodities

NFPA 61C, *Standard for the Prevention of Fire and Dust Explosions in Feed Mills*

NFPA 61D, *Standard for the Prevention of Fire and Dust Explosions in the Milling of Agricultural Commodities for Human Consumption*

NFPA 65, *Standard for the Processing and Finishing of Aluminum*

NFPA 480, *Standard for the Storage, Handling and Processing of Magnesium Solids and Powders*

NFPA 481, *Standard for the Production, Processing, Handling, and Storage of Titanium*

NFPA 482, *Standard for the Production, Processing, Handling, and Storage of Zirconium*

NFPA 490, *Code for the Storage of Ammonium Nitrate*

NFPA 651, *Standard for the Manufacture of Aluminum Powder*

NFPA 655, *Standard for Prevention of Sulfur Fires and Explosions*

NFPA 664, *Standard for the Prevention of Fires and Explosions in Wood Processing and Woodworking Facilities*

NFPA 8503, *Standard for Pulverized Fuel Systems.*

1-1.3

NFPA 91, *Standard for Exhaust Systems for Air Conveying of Materials,* shall not apply to material transfer systems or dust control systems covered by this standard.

1-2 Purpose.

The purpose of this standard is to prescribe requirements for safety to life and property from fire and explosion and to minimize the resulting damage should a fire or explosion occur.

1-3 Equivalency.

Nothing in this standard is intended to prevent the use of systems, methods, or devices of equivalent or superior quality, strength, fire resistance, effectiveness, durability, and safety over those prescribed by this standard, provided technical documentation is submitted to the authority having jurisdiction to demonstrate equivalency and the system, method, or device is approved for the intended purpose.

1-4 Retroactivity.

This standard applies to facilities on which construction is begun subsequent to the date of publication of the standard. When major replacement or renovation of existing facilities is planned, provisions of this standard shall apply.

1-5 Definitions.

For the purpose of this standard, the following terms shall have the meanings given below.

Approved. Acceptable to the authority having jurisdiction.

NOTE: The National Fire Protection Association does not approve, inspect, or certify any installations, procedures, equipment, or materials; nor does it approve or evaluate testing laboratories. In determining the acceptability of installations, procedures, equipment, or materials, the authority having jurisdiction may base acceptance on compliance with NFPA or other appropriate standards. In the absence of such standards, said authority may require evidence of proper installation, procedure, or use. The authority having jurisdiction may also refer to the listings or labeling practices of an organization concerned with product evaluations that is in a position to determine compliance with appropriate standards for the current production of listed items.

Authority Having Jurisdiction. The organization, office, or individual responsible for approving equipment, an installation, or a procedure.

NOTE: The phrase “authority having jurisdiction” is used in NFPA documents in a broad manner, since jurisdictions and approval agencies vary, as do their responsibilities. Where public safety is primary, the authority having jurisdiction may be a federal, state, local, or other regional department or individual such as a fire chief; fire marshal; chief of a fire prevention bureau, labor department, or health department; building official; electrical inspector; or others having statutory authority. For insurance purposes, an insurance inspection department, rating bureau, or other insurance company representative may be the authority having jurisdiction. In many circumstances, the property owner or his or her designated agent assumes the role of the authority having jurisdiction; at government installations, the commanding officer or departmental official may be the authority having jurisdiction.

Chemical. A substance composed of an element or combination of elements.

Combustible Dust.* Any finely divided solid material 420 microns or smaller in diameter (material passing a U.S. No. 40 Standard Sieve) that presents a fire or explosion hazard when dispersed and ignited in air.

Detachment. In the open air or in a separate building.

Duct. Pipes, channels, or other enclosures used for the purpose of conveying air, dust, or gas. A duct shall not include short sections of flexible hose.

Dye. A solid or powdered coloring matter.

Explosion. The bursting of a building or container as a result of development of internal pressure beyond its confinement capacity.

Hybrid Mixture.* A mixture of a combustible gas with either a combustible dust or a combustible mist.

Labeled. Equipment or materials to which has been attached a label, symbol, or other identifying mark of an organization that is acceptable to the authority having jurisdiction and concerned with product evaluation that maintains periodic inspection of production of labeled equipment or materials and by whose labeling the manufacturer indicates compliance with appropriate standards or performance in a specified manner.

Listed. Equipment or materials included in a list published by an organization acceptable to the authority having jurisdiction and concerned with product evaluation that maintains periodic inspection of production of listed equipment or materials and whose listing states either that the equipment or material meets appropriate standards or has been tested and found suitable for use in a specified manner.

NOTE: The means for identifying listed equipment may vary for each organization concerned with product evaluation, some of which do not recognize equipment as listed unless it is also labeled. The authority having jurisdiction should utilize the system employed by the listing organization to identify a listed product.

Pharmaceutical. A natural or manufactured medicinal drug composed of various ingredients.

Plastic. A generic term referring to synthetic or natural resins, with or without additives, that can be molded by heat and pressure, or both. The term also refers to the finished products.

Separation. The interposing of distance between the combustible dust process and other operations that are in the same room.

Segregation. The interposing of a physical barrier between the combustible dust process and other operations.

Shall. Indicates a mandatory requirement.

Should. Indicates a recommendation or that which is advised but not required.

Chapter 2 Plant Arrangement and Building Construction

2-1 Segregation, Separation, or Detachment of Dust Handling and Processing Areas.

2-1.1

Areas in which combustible dusts are processed or handled shall be segregated, separated, or detached in such a manner as to minimize damage to other portions of the plant should an explosion or fire occur. (*See 3-3.2.4.*)

2-1.2

If physical barriers are erected to segregate dust explosion hazards, they shall be designed for sufficient explosion resistance to preclude failure of these barriers before the explosion pressure can be safely vented to the outside.

2-1.3

Compartmentation shall be permitted to be used to limit the area considered hazardous, provided a dust collection system is installed to minimize accumulations of dust. Process equipment, including the dust collection system, shall be protected as required by Chapters 3 and 4.

2-2 Building Construction.

2-2.1

All buildings shall be of Type I or II construction, as defined in NFPA 220, *Standard on Types of Building Construction*. Where local, state, and national building codes require, modifications shall be permitted for conformance to these codes.

2-2.2*

Interior surfaces shall be as smooth as possible to facilitate cleaning and minimize combustible dust accumulation.

2-2.3

Concealed spaces shall be sealed to prevent dust accumulation.

2-2.4

Interior walls erected as fire partitions shall be designed for a minimum fire endurance of 1 hour.

2-2.5

Openings in fire walls shall be protected by automatic closing fire doors having a fire protection rating of 3 hours. Fire doors shall be installed according to NFPA 80, *Standard for Fire Doors and Fire Windows*, and shall normally be in the closed position.

2-2.6

Means of egress shall comply with NFPA *101®*, *Life Safety Code®*.

2-2.7

All penetrations of floors, walls, or partitions shall be dusttight and, where structural assemblies have a fire endurance rating, the seal shall maintain that rating.

2-2.8

Interior stairs, elevators, and manlifts shall be enclosed in dusttight shafts having a 1-hour fire resistance rating. Doors of the automatic-closing or self-closing type, having a fire protection rating of 1 hour, shall be provided at each landing.

Exception: Stairs, elevators, and manlifts serving only open-deck floors, mezzanines, and platforms need not be enclosed.

2-2.9*

Floors and load bearing walls exposed to dust explosion hazards shall be designed to preclude failure during an explosion.

2-3 Explosion Venting.

2-3.1*

If a room or building contains a dust explosion hazard external to protected equipment, such areas shall be provided with explosion venting to a safe outside location.

2-3.2*

Vent closures shall be directed toward a personnel restricted area, or the vent closure shall be restrained to minimize the missile hazard to personnel and equipment. In addition to the missile hazard, the fireball emitted from the vent opening shall not impinge upon personnel pathways.

2-3.3

Explosion vents shall be designed such that, once opened, they will remain open to prevent failure from the vacuum following the pressure wave.

Chapter 3 Process Equipment

3-1* General.

3-1.1 Equipment Explosion Protection.

In designing explosion protection for equipment, one of the following methods of protection shall be incorporated:

(a) Equipment can be designed to contain the anticipated explosion pressure in accordance with NFPA 69, *Standard on Explosion Prevention Systems*.

(b)* Explosion venting can be provided.

(c) An explosion suppression system shall be permitted to be provided and, where used, shall be designed in accordance with NFPA 69, *Standard on Explosion Prevention Systems*.

(d)* Inerting shall be permitted to be used to reduce oxygen content below the specific level for the material being handled. See NFPA 69, *Standard on Explosion Prevention Systems*.

(e) The dust shall be permitted to be rendered noncombustible through dilution with a noncombustible dust. If this method is used, test data for specific dust and diluent combinations shall be provided and shall be acceptable to the authority having jurisdiction.

3-1.2 Equipment Isolation.

Isolation devices shall be provided to prevent explosion propagation between major pieces of equipment connected by ductwork, or the design shall take into consideration the increased venting requirements from pressure piling and flame jet ignition. Isolation devices include, but are not limited to:

(a)* Chokes,

(b)* Rotary valves,

(c) Fast-acting dampers and valves,

(d) Flame front diverters,

(e) Deflagration isolation systems.

(See NFPA 69, *Standard on Explosion Prevention Systems*, for design requirements.)

3-2 Bulk Storage.

3-2.1

For the purpose of this section, bulk storage shall include such items as bins, tanks, hoppers, and silos.

3-2.2

Bulk storage containers, whether located inside or outside of buildings, shall be constructed of noncombustible material.

3-2.3

There shall be no intertank or interbin venting.

3-2.4*

Interior surfaces shall be as smooth as possible to facilitate cleaning and minimize combustible dust accumulation.

3-2.5

Access doors or openings shall be provided to permit inspection, cleaning, and maintenance. Access doors or openings shall be designed to prevent dust leaks. Access doors shall not be considered as an explosion relief area unless specifically designed for that function and vented to outside the building.

3-2.6

Bulk storage containers shall be provided with explosion protection as described in 3-1.1.

3-3 Material Transfer System.

3-3.1 Duct Systems.

3-3.1.1* Ducts handling combustible dust shall be constructed of noncombustible material, shall be of adequate strength and rigidity to meet the conditions of service and installation requirements, and shall be properly protected where subject to mechanical injury. All ducts, whether inside or outside of buildings, shall be thoroughly braced where required and substantially supported by metal hangers or brackets and shall be designed to afford strength and rigidity against disruption. All lap joints shall be made in the direction of the air flow.

Exception: Flexible hose to allow material pick-up, flexible connections for vibration isolation, and bellows for the free movement of weigh bins shall be permitted if they are conductive or the equipment is bonded and grounded.*

3-3.1.2 All ducts shall be made reasonably dusttight throughout and shall have no openings other than those required for the proper operation and maintenance of the system, i.e., clean-out panels, service access panels for explosion vents, etc.

3-3.1.3 Changes in sizes of ducts shall be by means of a taper transformation piece, the included angle of the taper being not more than 30 degrees.

3-3.1.4 The passing of ducts through a physical barrier for segregation shall be avoided.

3-3.2 Bucket Elevators.

3-3.2.1 Belt-driven bucket elevators shall be provided with explosion protection as specified in 3-1.1. Bucket elevators, wherever possible, shall be located outside buildings. Where explosion venting is provided, the bucket elevator shall be located as close as possible to exterior walls where explosion relief can be vented to the outside. If the distance between the head and boot exceeds 20 ft (6.1 m), explosion relief shall be provided at not more than 20-ft (6.1-m) intervals on the legs.

3-3.2.2 Elevator leg casings, head and boot sections, and connecting ducts shall be dusttight and shall be constructed of noncombustible materials.

3-3.2.3 Where provided, inlet and discharge hoppers shall be designed so that they are accessible for cleaning and inspection.

3-3.2.4* Belt-driven bucket elevators shall be equipped with a mechanical or electromechanical device that cuts off the power to the drive motor and sounds an alarm in the event of leg belt slowdown exceeding 20 percent. Feed to the elevator leg shall be stopped or diverted.

3-3.2.5 No bearings shall be located or exposed within the bucket elevator casing.

3-3.3 Conveyors.

3-3.3.1 All conveyors (e.g., screw, drag, pneumatic, etc.) shall be of metal construction and shall be designed to prevent escape of combustible dusts. Coverings on clean-out, inspection, and other openings shall be securely fastened.

3-3.3.2* Pneumatic systems shall be designed in accordance with NFPA 650, *Standard for Pneumatic Conveying Systems for Handling Combustible Materials*.

3-3.3.3 Conveyors shall be protected from explosion as specified in 3-1.1.

3-3.3.4 Belt-driven conveyors shall be equipped with an automechanical or an electromechanical device that cuts off the power to the drive motor and sounds an alarm in the event of a belt slowdown exceeding 20 percent. Feed to the conveyor shall be stopped or diverted.

3-3.4 Fans or Blowers.

3-3.4.1 Blowers or exhaust fans shall be installed on proper foundations and shall be secured in a substantial manner.

3-3.4.2 For fans, ample clearance shall be provided between the blades and the casing, and fans shall be designed to operate below the minimum explosible concentration of the normally expected dust and hybrid loading.

3-3.4.3* For fans on the discharge side of the dust collectors, the dust concentration in the system shall be designed to be below the minimum explosible concentration of the normally expected dust and hybrid loading.

3-3.4.4 The fan bearings shall not extend into the casings. Belt drives shall not be located inside the fan or blower housing. A clearance shall be provided between the shaft and casings.

3-3.4.5 A minimum conveying velocity shall be maintained throughout the conveying system to prevent the accumulation of dust at any point and to pick up any dust or powder that drops out during an unscheduled system stoppage.

3-4 Size Reduction.

3-4.1

Size reduction equipment shall include such items as mills, grinders, and pulverizers.

3-4.2

Before material is processed by size reduction equipment, foreign matter shall be removed as required by 5-1.1 or by the use of grates or other separation devices.

3-4.3

Size reduction equipment shall be isolated as required by 3-1.2.

3-4.4

Explosion protection shall be provided as specified in 3-1.1.

3-5* Particle Size Separation.

Screens, sieves, and similar devices shall be in dusttight enclosures. Connection ducts shall be made of metal.

Exception: Where movement of the equipment is necessary, short flexible connections shall be permitted to be used. Such connectors shall be electrically conductive and bonded. (See Section 5-3.)

3-6 Mixers and Blenders.

3-6.1*

Mixers and blenders shall be dusttight. Foreign matter shall be removed as required by 5-1.1 or by the use of grates or other separation devices.

3-6.2

Explosion protection shall be provided as specified in 3-1.1.

3-6.3

Mixers and blenders shall be made of metal or other noncombustible material.

3-7 Dryers.

3-7.1*

A dryer, within the scope of this standard, shall be any piece of processing equipment used to reduce the moisture or volatile content of the material being handled.

3-7.2*

Heating systems shall be in accordance with 5-5.1.

3-7.3

Drying media that contacts material being processed shall not be recycled to rooms or buildings. Drying media shall be permitted to be passed through a filter, dust separator, or equivalent means of dust removal and recycled to the drying process.

3-7.4

Dryers shall be isolated as required by 3-1.2.

3-7.5

Combustion controls on all heating mediums shall be provided in accordance with the following NFPA standards, as applicable:

NFPA 31, *Standard for the Installation of Oil-Burning Equipment*

NFPA 85C, *Standard for Prevention of Furnace Explosions/Implosions in Multiple Burner Boiler-Furnaces*

NFPA 86, *Standard for Ovens and Furnaces*

NFPA 8501, *Standard for Single Burner Boiler Operation.*

3-7.6

Dryers shall be constructed of noncombustible materials.

3-7.7

Interior surfaces of dryers shall be designed so that accumulations of material are minimized and cleaning is facilitated.

3-7.8

Outward opening access doors or openings shall be provided in all parts of the dryer and connecting conveyors to permit inspection, cleaning, maintenance, and the effective use of portable extinguishers or hose streams.

3-7.9

Explosion protection shall be provided as specified in 3-1.1.

3-7.10 Dryer Operation.

3-7.10.1 Operating controls shall be designed, constructed, installed, and monitored so that required conditions of safety for operation of the air heater, the dryer, and the ventilation equipment are maintained.

3-7.10.2 The drying chamber shall have an operating control arranged to maintain the temperature within the prescribed limits.

3-7.10.3 Extraneous material that would contribute to a fire hazard shall be removed from the commodity before it enters the dryer.

3-7.10.4 Operating personnel shall be fully instructed on the safe operation of the dryer, according to the manufacturer's operating instructions. Instruction shall include procedures to be followed in case of fire.

Chapter 4 Dust Control

4-1 Dust Collection.

4-1.1

Continuous suction shall be provided for processes where combustible dust is liberated in normal operation. The dust shall be conveyed to dust separators or collectors.

4-1.2 Location and Provisions for Dust Collection Systems.

4-1.2.1* Dust collectors shall be located outside of buildings.

Exception No. 1: Dust collectors shall be permitted to be located inside of buildings if they are located adjacent to an exterior wall, are vented to the outside through straight ducts not exceeding 10 ft (3 m) in length, and have explosion vents.*

Exception No. 2: Dust collectors protected with an explosion suppression system meeting the requirements of NFPA 69, Standard on Explosion Prevention Systems, shall be permitted to be located inside buildings.

4-1.2.2 Dust collection equipment shall be provided with explosion protection, as specified in 3-1.1.

4-1.3

Manifolding of dust collection ducts shall not be permitted unless arranged in accordance with 4-1.3.1 and 4-1.3.2.

4-1.3.1 Dust collection ducts from a single piece of equipment or from multiple pieces of equipment interconnected on the same process stream shall be permitted to be manifolded.

4-1.3.2 Dust collection ducts from isolated pieces of equipment shall be permitted to be manifolded if each of the ducts is equipped with an isolation device prior to manifolding.

4-1.4

Dust collectors shall be constructed of noncombustible materials. Cloth-type collectors shall be provided with dusttight metal enclosures or their equivalent.

4-1.5

Recycling of air from collectors to buildings shall be permitted if the system is designed to prevent both return of dust and transmission of energy from a fire or explosion to the building.

Exception: Recycling of air to the building shall not be permitted under any circumstances when combustible gases or vapors, hybrid mixtures, or inert gases are involved.

4-2 Housekeeping.

The requirements of 4-2.1 through 4-2.4 shall be applied retroactively.

4-2.1*

Equipment shall be designed, maintained, and operated in a manner that minimizes the escape of dust. Regular cleaning frequencies shall be established for floors and horizontal surfaces, such as ducts, pipes, hoods, ledges, and beams to minimize dust accumulations within operating areas of the facility.

4-2.2*

Surfaces shall be cleaned in a manner that minimizes the generation of dust clouds. Vigorous sweeping, blowing down with steam or compressed air produces dust clouds and shall be permitted only if the requirements of 4-2.3 are met.

4-2.3

Blowdown with steam or compressed air can be performed if the following items are complied with:

(a) Area and equipment shall be vacuumed prior to blowdown.

(b) Electrical power and other sources of ignition shall be shut down or removed from the area.

(c) Only low-pressure steam or compressed air shall be used.

4-2.4

When used, vacuum cleaners shall be listed for use in Class II hazardous locations or shall be a fixed-pipe suction system with remotely located exhauster and collector.

Exception: Where flammable vapors or combustible gases are present, vacuum cleaners shall be listed for Class I hazardous locations.

Chapter 5 Control of Ignition Sources

5-1 Friction.

5-1.1* Tramp Metal.

Magnetic separators of the permanent magnet or self-cleaning electromagnetic type or pneumatic separators shall be installed to remove metal or foreign matter capable of igniting combustible material being processed. [*See Figures A-3-1.2(a) and (b).*]

5-1.2*

Belt drives shall be designed to stall without slipping, or a safety device shall be provided to shut down the equipment if slippage occurs.

5-1.3 Bearings.

5-1.3.1 Roller or ball antifriction bearings shall be used on all processing and transfer equipment.

Lubrication shall be performed in accordance with the manufacturer's recommendations.

5-1.3.2 Wherever possible, bearings shall be located outside the combustible dust stream where they are less exposed to dust and more accessible for inspection and service.

5-1.4 Equipment.

5-1.4.1 Equipment shall be installed and maintained so that constant true alignment is maintained and adequate clearance is provided to minimize friction.

5-1.4.2 Equipment such as screw conveyors or drag conveyors shall be arranged to shut down if the discharge opening becomes plugged.

5-2 Electrical Equipment.

All electrical equipment and installations shall comply with the requirements of NFPA 70, *National Electrical Code®*, or NFPA 496, *Standard for Purged and Pressurized Enclosures for Electrical Equipment*, as applicable.

5-3* Static Electricity.

All machines and equipment, including duct work, storage bins, and permanently installed and portable vacuum cleaning systems, shall be bonded and grounded. Where belt drives are used, the belts shall be of electrically conductive material. Ionization methods shall be used to dissipate static electricity in nonconducting equipment. The utilization of flexible intermodel bulk containers shall not be permitted where flammable gases or combustible vapors are present.

5-4 Open Flames and Sparks.

The requirements of 5-4.1 through 5-4.3 shall be applied retroactively.

5-4.1

Cutting and welding shall comply with the applicable requirements of NFPA 51B, *Standard for Fire Prevention in Use of Cutting and Welding Processes*.

5-4.2

A hot work permit system shall be used for any process resulting in sparks or using open flames in areas where combustible dust is present. Precautions shall be similar to those required in 5-4.1 for cutting and welding operations.

5-4.3

Smoking shall be permitted only in designated areas.

5-5 Heating Systems.

5-5.1 Process Heating Systems.

5-5.1.1 Process heating systems using air, steam, or heat transfer fluids shall be provided with pressure relief valves where necessary. Relief valves on systems employing combustible heat transfer media shall be vented to a safe outside location.

5-5.1.2 Heaters for heat transfer media shall be located in a separate, dust-free room or building, or outdoors.

5-5.1.3 Air for combustion shall be taken from a clean outside source.

5-5.1.4 Heat exchangers shall be located and arranged in a manner that does not allow combustible dust to accumulate on coils, fins, or other heated surfaces.

5-5.1.5 Where a system employs combustible heat transfer media, automatic sprinkler protection shall be provided in accordance with NFPA 13, *Standard for the Installation of Sprinkler Systems*.

5-5.2 Comfort Heating.

5-5.2.1 In areas containing combustible dust, comfort heating, if provided, shall be provided by indirect means or a means suitable for the location.

5-5.2.2 If used, hot water or low-pressure steam (15 psig or less) shall be supplied by a boiler installed in accordance with 5-5.1.2.

5-5.2.3 Hot air heaters shall be installed in accordance with 5-5.1.2. Air containing combustible dust shall not be circulated back to the heater, nor shall it be recirculated to nonhazardous areas of the building.

5-5.2.4 Steam and hot water supply pipes and hot air supply ducts in areas containing combustible dust shall be fitted with properly maintained insulation having a continuous nonporous covering and having a thickness sufficient to keep the temperature of the outer surface below 80 percent of the minimum ignition temperature of the dust layer.

5-6 Hot Surfaces.

The temperature of all exposed surfaces (engines, pipes, ducts, process equipment) within an area containing a combustible dust shall be maintained below 80 percent of the minimum ignition temperature of the dust layer.

5-7 Industrial Trucks.

In areas containing a combustible dust hazard, only industrial trucks of a type suitable for the electrical classification of the area shall be used. See NFPA 505, *Fire Safety Standard for Powered Industrial Trucks Including Type Designations, Areas of Use, Maintenance, and Operation*, and Articles 500 and 502 of NFPA 70, *National Electrical Code*.

5-8 Powder-Actuated Tools.

5-8.1

Powder-actuated tools shall not be used in areas where combustible dust is present.

5-8.2

When the use of powder actuated tools becomes necessary, all dust-producing machinery in the area shall be shut down; all equipment, floors, and walls shall be cleaned carefully; and all dust accumulations shall be removed.

5-8.3

A thorough check shall be made after the work is completed to be sure that no cartridges or charges are left on the premises where they can enter equipment or be accidentally discharged after operation of the dust-producing or handling machinery is resumed.

Chapter 6* Fire Protection

6-1 Fire Extinguishers.

Portable fire extinguishers shall be provided throughout all buildings according to the requirements of NFPA 10, *Standard for Portable Fire Extinguishers*.

6-2 Hose, Standpipes, and Hydrants.

6-2.1

Standpipes and hose, where provided, shall comply with NFPA 14, *Standard for the Installation of Standpipe and Hose Systems*.

6-2.2

Electrical-type (or equivalent) spray nozzles shall be provided in areas containing dust in order to limit the potential for generating unnecessary airborne dust during fire-fighting operations.

6-2.3

Private outside protection, including outside hydrants and hoses, where provided, shall comply with NFPA 24, *Standard for the Installation of Private Fire Service Mains and Their Appurtenances*.

6-3* Automatic Sprinklers.

Automatic sprinklers, where provided, shall be installed in accordance with NFPA 13, *Standard for the Installation of Sprinkler Systems*.

6-4 Special Fire Protection Systems.

Automatic extinguishing systems or special hazard extinguishing systems, where provided, shall be designed, installed, and maintained in accordance with the following standards as applicable. The extinguishing systems shall be designed and used to minimize the generation of dust clouds during their discharge.

(a) NFPA 11, *Standard for Low-Expansion Foam*

(b) NFPA 11A, *Standard for Medium- and High-Expansion Foam Systems*

(c) NFPA 12, *Standard on Carbon Dioxide Extinguishing Systems*

(d) NFPA 12A, *Standard on Halon 1301 Fire Extinguishing Systems*

(e) NFPA 12B, *Standard on Halon 1211 Fire Extinguishing Systems*

(f) NFPA 15, *Standard for Water Spray Fixed Systems for Fire Protection*

(g) NFPA 16, *Standard on the Installation of Deluge Foam-Water Sprinkler and Foam-Water Spray Systems*

(h) NFPA 17, *Standard for Dry Chemical Extinguishing Systems*

(i) NFPA 72, *National Fire Alarm Code*

6-5 Alarm Service.

Alarm service, if provided, shall comply with NFPA 72, *National Fire Alarm Code*.

Chapter 7 Training, Inspection, and Maintenance

7-1 Employee Training.

7-1.1

There shall be policies and requirements that provide for initial and continuing training for all employees. These shall include the development of operating procedures that are reviewed at least once per year and after every process change.

7-1.2

All employees shall be instructed at scheduled intervals regarding the potential hazards of their working environment and their behavior and procedures in case of equipment or process failures that can result in fire or explosion.

7-2 Periodic Inspection.

7-2.1

A systematic inspection for safe operations shall be made at regular intervals, and reports shall be submitted to plant management for review.

The inspection shall include:

(a) Fire and explosion protection and prevention equipment;

(b) Dust control equipment;

(c) Housekeeping;

(d) Potential ignition sources;

(e)* Electrical, process, and mechanical equipment, including interlocks; and

(f) Standard operating procedures and work practices.

7-2.2

Competent persons shall conduct inspections and the record of their findings and recommendations shall be recorded permanently in the principal plant office.

7-2.3*

An emergency plan shall be maintained up-to-date and shall be coordinated with existing local community emergency planning.

7-3 Maintenance.

7-3.1

A planned maintenance system shall be established to regularly lubricate, inspect, and test electrical and mechanical equipment in accordance with the manufacturer’s recommendations.

7-3.2

A recordkeeping system of repairs and planned maintenance shall be established.

Chapter 8 Referenced Publications

8-1

The following documents or portions thereof are referenced within this standard and shall be considered part of the requirements of this document. The edition indicated for each reference is the current edition as of the date of the NFPA issuance of this document.

8-1.1 NFPA Publications.

National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.

NFPA 10, *Standard for Portable Fire Extinguishers*, 1990 edition.

NFPA 11, *Standard for Low-Expansion Foam*, 1994 edition.

NFPA 11A, *Standard for Medium- and High-Expansion Foam Systems*, 1994 edition.

NFPA 12, *Standard on Carbon Dioxide Extinguishing Systems*, 1993 edition.

NFPA 12A, *Standard on Halon 1301 Fire Extinguishing Systems*, 1992 edition.

NFPA 12B, *Standard on Halon 1211 Fire Extinguishing Systems*, 1990 edition.

NFPA 13, *Standard for the Installation of Sprinkler Systems*, 1994 edition.

NFPA 14, *Standard for the Installation of Standpipe and Hose Systems*, 1993 edition.

NFPA 15, *Standard for Water Spray Fixed Systems for Fire Protection*, 1990 edition.

NFPA 16, *Standard on the Installation of Deluge Foam-Water Sprinkler and Foam-Water Spray Systems*, 1991 edition.

NFPA 17, *Standard for Dry Chemical Extinguishing Systems*, 1994 edition.

NFPA 24, *Standard for the Installation of Private Fire Service Mains and Their Appurtenances*, 1992 edition.

NFPA 31, *Standard for the Installation of Oil-Burning Equipment*, 1992 edition.

NFPA 51B, *Standard for Fire Prevention in Use of Cutting and Welding Processes*, 1994 edition.

NFPA 61A, *Standard for the Prevention of Fire and Dust Explosions in Facilities Manufacturing and Handling Starch*, 1989 edition.

NFPA 61B, *Standard for the Prevention of Fires and Explosions in Grain Elevators and Facilities Handling Bulk Raw Agricultural Commodities*, 1989 edition.

NFPA 61C, *Standard for the Prevention of Fire and Dust Explosions in Feed Mills*, 1989 edition.

NFPA 61D, *Standard for the Prevention of Fire and Dust Explosions in the Milling of Agricultural Commodities for Human Consumption*, 1989 edition.

NFPA 65, *Standard for the Processing and Finishing of Aluminum*, 1993 edition.

NFPA 69, *Standard on Explosion Prevention Systems*, 1992 edition.

NFPA 70, *National Electrical Code*, 1993 edition.

NFPA 72, *National Fire Alarm Code*, 1993 edition.

NFPA 80, *Standard for Fire Doors and Fire Windows*, 1992 edition.

NFPA 85C, *Standard for Prevention of Furnace Explosions/Implosions in Multiple Burner Boiler-Furnaces*, 1991 edition.

NFPA 86, *Standard for Ovens and Furnaces*, 1990 edition.

NFPA 91, *Standard for Exhaust Systems for Air Conveying of Materials*, 1992 edition.

NFPA *101*, *Life Safety Code*, 1994 edition.

NFPA 220, *Standard on Types of Building Construction*, 1992 edition.

NFPA 480, *Standard for the Storage, Handling and Processing of Magnesium Solids and Powders*, 1993 edition.

NFPA 481, *Standard for the Production, Processing, Handling, and Storage of Titanium*, 1987 edition.

NFPA 482, *Standard for the Production, Processing, Handling, and Storage of Zirconium*, 1987 edition.

NFPA 490, *Code for the Storage of Ammonium Nitrate*, 1993 edition.

NFPA 496, *Standard for Purged and Pressurized Enclosures for Electrical Equipment*, 1993 edition.

NFPA 650, *Standard for Pneumatic Conveying Systems for Handling Combustible Materials*, 1990 edition.

NFPA 651, *Standard for the Manufacture of Aluminum Powder*, 1993 edition.

NFPA 655, *Standard for Prevention of Sulfur Fires and Explosions*, 1993 edition.

NFPA 664, *Standard for the Prevention of Fires and Explosions in Wood Processing and Woodworking Facilities*, 1993 edition.

NFPA 8501, *Standard for Single Burner Boiler Operations*, 1992 edition.

NFPA 8503, *Standard for Pulverized Fuel Systems*, 1992 edition.

Appendix A Explanatory Material

This Appendix is not a part of the requirements of this NFPA document but is included for informational purposes only.

A-1-5 Combustible Dust.

Any time a combustible dust is processed or handled, a potential for deflagration exists. The degree of deflagration hazard will vary depending on the type of combustible dust and processing methods used.

A dust deflagration has three requirements, all of which must be met:

(a) The dust must be combustible.

(b) The dust particles must form a cloud in an oxidizing gas at or exceeding the minimum explosive concentration.

(c) A source of ignition must be present.

Evaluation of a combustible dust explosion hazard and the prevention techniques employed are determined by means of actual test data. All combustible dusts that can produce a dust explosion should be tested to determine the following data:

(a) Particle size distribution;

(b) Moisture content as received and dried;

(c) Minimum dust concentration to ignite;

(d) Minimum energy required for ignition (joules);

(e) Maximum rate of pressure rise at various concentrations;

(f) Layer ignition temperature; and

(g) Maximum explosion pressure, at optimum concentration.

Optional testing should include:

(a) Dust cloud ignition temperature.

(b) Maximum permissible oxygen content to prevent ignition.

(c) Electrical resistivity measurement.

A-1-5 Hybrid Mixtures.

The presence of flammable gases and vapors, even at concentrations less than the lower explosive limit (LEL) of the flammable gases and vapors, will add to the violence of a dust-air combustion. The resulting dust/vapor mixture is called a "hybrid mixture" and is discussed in NFPA 68, *Guide for Venting of Deflagrations*.

Hybrid mixtures can be of concern even if the dust is normally considered to be "nonexplosive." For example, polyvinyl chloride is considered to be a "nonexplosive" dust. However, tests have shown that PVC can form explosive hybrid mixtures with methane at concentrations below the lower explosive limit.

A-2-2.2

Window ledges, girders, beams, and other horizontal projections or surfaces can have the tops sharply sloped, or other provisions can be made to minimize the deposit of dust thereon. Overhead steel I-beams or similar structural shapes can be boxed with concrete or other noncombustible material to eliminate surfaces for dust accumulation.

A-2-2.9

The use of load bearing walls should be avoided to prevent structural collapse should an explosion occur.

A-2-3.1

The design of explosion venting should be based on information contained in NFPA 68, *Guide for Venting of Deflagrations*.

A-2-3.2

For further information on restraining vent closures, see NFPA 68, *Guide for Venting of Deflagrations*.

A-3-1

The following items are areas of concern during the design and installation of process equipment.

(a) The elimination of friction by use of detectors for slipping belts, temperature supervision of moving or impacted surfaces, etc.

(b) Pressure resistance or maximum pressure containment capability and pressure relieving capabilities of:

1. The machinery or process equipment,

2. The building or room.

(c) The proper classification of electrical equipment for the area and condition.

(d) Proper alignment and mounting to minimize or eliminate vibration and overheated bearings.

(e) The use of electrically conductive belting, low speed belts, and short center drives as a means of reducing static electricity accumulation. See Section 5-3.

(f) When power is transmitted to apparatus within the processing room by belt or chain, it should be encased in a practically dusttight enclosure, constructed of substantial noncombustible material that should be maintained under positive air pressure. Where power is transmitted by means of shafts, these should pass through close-fitting shaft holes in walls or partitions.

A-3-1.1(b) For explosion relief venting through ducts, consideration should be given to the thrust forces generated and the length of the ducts. The relief duct should be restricted to no more than three meters. Where explosion venting is used, its design should be based on information contained in NFPA 68, *Guide for Venting of Deflagrations*.

A-3-1.1(d) Inerting also can be done by product dilution using a noncombustible dust, such as talc or lime, to reduce the concentration of the combustible dust to below the minimum explosive concentration. This technique is used in coal mines.

A-3-1.2(a) The following diagrams illustrate two different designs of chokes.

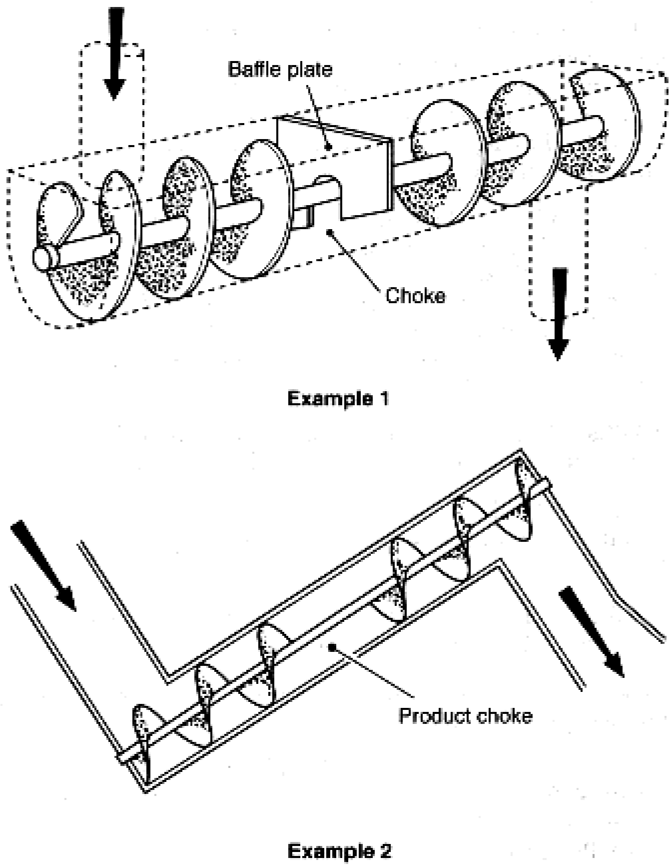


Figure A-3-1.2(a) Screw conveyor chokes.

A-3-1.2(b) When rotary valves are installed in both the inlet and outlet of equipment, care should be taken to ensure that the rotary valve on the inlet is stopped before the unit becomes overfilled. See Figure A-3-1.2(b).

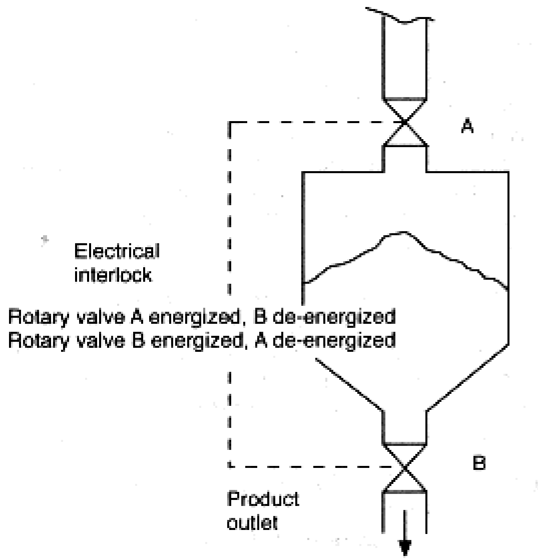


Figure A-3-1.2(b) Rotary valves.

A-3-2.4

Horizontal projections can have the tops sharply sloped to minimize the deposit of dust thereon. Efforts should be made to minimize the amount of surfaces where dust can accumulate.

A-3-3.1.1 Ducts for dust conveying systems should be as straight as possible; right angle bends should be avoided.

A-3-3.1.1 Exception For information on bonding and grounding, see NFPA 77, *Recommended Practice on Static Electricity*.

A-3-3.2.4 Where it is desired to prevent propagation of an explosion from the elevator leg to another part of the facility, an explosion blocking system should be provided at the head, boot, or at both locations.

A-3-3.3.2 Some chemical and plastic dusts release residual flammable vapors such as residual solvents, monomers, or resin additives. These vapors can be released from the material in the conveying system or in its final storage unit. Design of the system should be based on a minimum air flow sufficient to keep the concentration of the particular flammable vapor in the air stream below 25 percent of the lower explosive limit of the vapor.

Start-up and shutdown periods are the times when pneumatic conveying systems pass through the explosive range. Correct sequencing can reduce this:

Start-up: Full air first; then full load dust flow.

Shutdown: Dust stop quickly first; then run full air flow to clean.

A-3-3.4.3 Dusts should not pass through a fan or blower.

A-3-5

Explosion protection should be provided when the hazard is significant. (*See 3-1.1.*)

A-3-6.1

Mixers and blenders should, where possible, operate under slight negative pressure to avoid emitting dust to the immediate atmosphere.

A-3-7.1

Dryers commonly found in industry include tray, drum, rotary, fluidized bed, pneumatic, spray, and vacuum.

A-3-7.2

Heating by indirect means is less hazardous than by direct means and is therefore preferred. Improved protection can be provided for direct-fired dryers by providing an approved automatic spark detection and extinguishing system.

A-4-1.2.1 For information on designing explosion vents, see NFPA 68, *Guide for Venting of Deflagrations*.

A-4-2.1

A relatively small initial dust explosion will disturb and suspend in air dust that has been allowed to accumulate on the flat surfaces of a building or equipment. This dust cloud provides fuel for the secondary explosion, which usually causes the major portion of the damage. Reducing dust accumulations is, therefore, a major factor in reducing the hazard in areas where a dust hazard can exist.

Using a bulk density of 75 lb/ft^3 (1200 kg/m^3) and an assumed concentration of 0.35 oz/ft^3 (350 g/m^3), it has been calculated that a dust layer that averages $^1/_{32}$ in. (0.8 mm) thick covering the floor of a building is sufficient to produce a uniform dust cloud of optimum concentration, 10 ft (3 m) high, throughout the building. This is an idealized situation and several factors should be considered.

First, the layer will rarely be uniform or cover all surfaces and, secondly, the layer of dust will probably not be completely dispersed by the turbulence of the pressure wave from the initial explosion. However, if only 50 percent of the $^1/_{32}$ in. (0.8 mm) thick layer is suspended, this is still sufficient material to create an atmosphere within the explosive range of most dusts.

Consideration should be given to the proportion of building volume that could be filled with an explosive dust concentration. Since floor area is a measure of volume, the percentage of floor area covered can be used as a measure of the hazard. For example, a 10 ft × 10 ft (3 m × 3 m) room with a $^1/_{32}$-in. (0.8-mm) layer of dust on the floor is obviously hazardous and should be cleaned. Now consider this same 100 ft^2 (9.3 m^2) area in a 2,025 ft^2 (188 m^2) building; this also is a moderate hazard. This area represents about 5 percent of a floor area and is about as much coverage as should be allowed in any plant. To gain proper perspective, the overhead beams and ledges should also be considered. Rough calculations show that the available surface area of the bar joist is about 5 percent of the floor area. For steel beams, the equivalent surface area can be as high as 10 percent.

From the above information, the following guidelines have been established:

(a) Dust layers $^1/_{32}$ in. (0.8 mm) thick can be sufficient to warrant immediate cleaning of the area [$^1/_{32}$ in. (0.8 mm) is about the diameter of a paper clip wire or the thickness of the lead in a mechanical pencil].

(b) The dust layer is capable of creating a hazardous condition if it exceeds 5 percent of the building floor area.

(c) Dust accumulation on overhead beams and joists contributes significantly to the secondary dust cloud and is approximately equivalent to 5 percent of the floor area. Other surfaces, such as the tops of ducts and large equipment, can also contribute significantly to the dust cloud potential.

(d) The 5 percent factor should not be used if the floor area exceeds 20,000 ft^2 (1858 m^2). In such cases, a 1,000 ft^2 (93 m^2) layer of dust is the upper limit.

(e) Due consideration should be given to dust that adheres to walls, since this is easily dislodged.

(f) Attention and consideration should also be given to other projections such as light fixtures that can provide surfaces for dust accumulation.

(g) Dust collection equipment should be monitored to be certain it is operating effectively. For example, dust collectors using bags operate most effectively between limited pressure drops of 3 in. to 5 in. of water (0.74 kPa to 1.24 kPa). An excessive decrease or low drop in pressure indicates insufficient coating to trap dust.

The energy required to ignite dust in air is about 10.0 millijoules or 20 to 50 times greater than that required to ignite flammable vapors. Surface voltage of less than 5,000 volts might be considered safe except that such voltages might be indicative of higher voltages elsewhere in the system. Ungrounded metal parts having such high voltages would be hazardous because the energy stored and deliverable would be much greater. The minimum bond and ground wire size recommended is No. 8 or No. 10 AWG.

The above guidelines will serve to establish a cleaning frequency.

A-4-2.2

Vacuum cleaning systems are preferred for this purpose.

A-5-1.1

See Figures A-5-1.1(a) and (b) for examples of tramp metal removal.

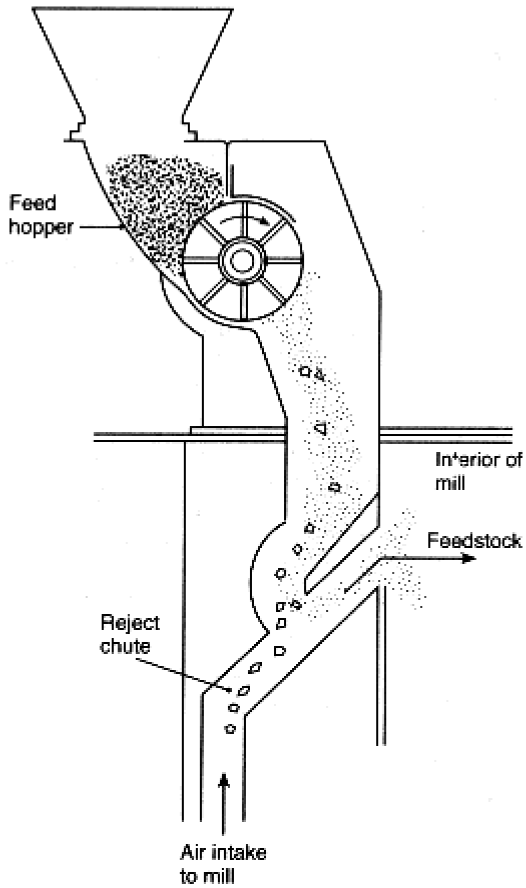


Figure A-5-1.1(a) Pneumatic separator.

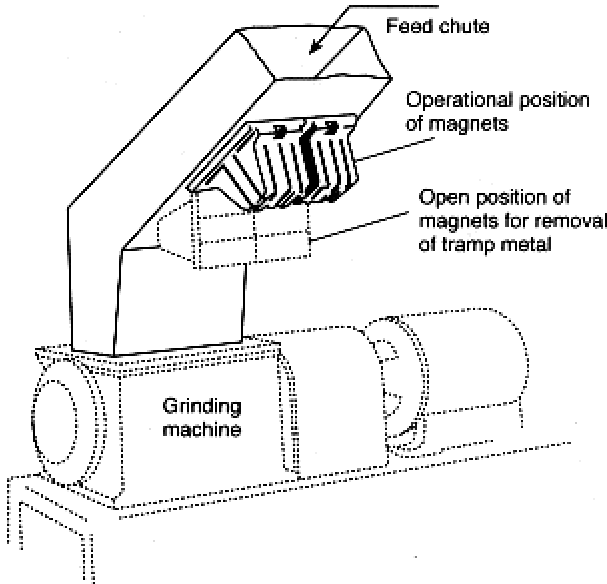


Figure A-5-1.1(b) Magnetic separator.

A-5-1.2

Transmission of power by direct drive should be used, where possible, in preference to belt or chain drivers.

A-5-3

Bonding minimizes the potential difference between metallic objects. Grounding minimizes the potential difference between objects and the ground. See NFPA 77, *Recommended Practice on Static Electricity*, for information on this subject.

A-6

Fire extinguishing equipment should be utilized in such a way to minimize the generation of dust clouds during the discharge.

A-6-3

Automatic sprinkler protection within dust collectors, silos, and bucket elevators should be considered. Considerations should include the combustibility of the equipment, the combustibility of the material, and the amount of material present. Where the combustible dust can react with water, automatic sprinkler systems should not be installed.

A-7-2.1

(e) Safety interlocks should be calibrated and tested every six months in the manner in which they are intended to operate with written test records maintained for review by management.

A-7-2.3

All plant personnel, including management, supervisors, and maintenance and operating personnel, should be trained to participate in plans for controlling plant emergencies. Trained plant fire squads or fire brigades should be maintained.

The elements of an emergency plan should:

(a) Include a signal or alarm systems.

(b) Include identification of means of egress.

(c) Minimize the effect on operating personnel and the community.

(d) Keep property and equipment losses to a minimum.

(e) Ensure interdepartmental and interplant cooperation.

(f) Ensure the cooperation of outside agencies.

(g) Promote the release of accurate information to the public.

Simulated emergency drills should be performed by process operators. Malfunctions of the process should be simulated and emergency actions undertaken. "Disaster" drills that simulate a major catastrophe situation should be undertaken periodically with the cooperation and participation of public fire, police, and other local community emergency units and nearby cooperating plants. The emergency plans should be tested annually.

Appendix B Referenced Publications

B-1

The following documents or portions thereof are referenced within this standard for informational purposes only and thus are not considered part of the requirements of this document. The edition indicated for each reference is the current edition as of the date of the NFPA issuance of this document.

B-1.1 NFPA Publications.

National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.

NFPA 68, *Guide for Venting of Deflagrations*, 1994 edition.

NFPA 69, *Standard on Explosion Prevention Systems*, 1992 edition.

NFPA 70, *National Electrical Code*, 1993 edition.

NFPA 77, *Recommended Practice on Static Electricity*, 1993 edition.

NFPA 505, *Fire Safety Standard for Powered Industrial Trucks Including Type Designations, Areas of Use, Maintenance, and Operation*, 1992 edition.

Formal Interpretation

NFPA 654

Dust Explosion Prevention in Chemical, Dye, Pharmaceutical, and Plastics Industries

1994 Edition

Reference : **2-1.1**
F.I. 82-1

Question 1: Based on NFPA 654, 2-1.1, reference to "areas in which combustible dusts are processed or handled shall be segregated, separated or detached in such a manner as to minimize damage to other portions of the plant . . .," is it the Code's intent that separation be provided between such an area and another portion of the facility which also processes or handles combustible dust?

Answer: No.

Question 2: More specifically, in a deoiling processing operation a slurry of combustible dust in a hydrocarbon oil passes through a vertical process train. Four identical trains are present alongside each other in a building within fifteen to twenty feet of each other. Is it the intent of 2-1.1 that each train be considered "another portion" of the plant or another "dust explosion hazard" and thus require separation from the other trains?

Answer: No.

Issue Edition: 1982
Reference:– 2-1
Date: August 1982

NFPA 655

1993 Edition

Standard for Prevention of Sulfur Fires and Explosions

1993 Edition

This edition of NFPA 655, *Standard for Prevention of Sulfur Fires and Explosions*, was prepared by the Technical Committee on Fundamentals of Dust Explosion Prevention and Control and acted on by the National Fire Protection Association, Inc. at its Annual Meeting held May 24-27, 1993, in Orlando, FL. It was issued by the Standards Council on July 23, 1993, with an effective date of August 20, 1993, and supersedes all previous editions.

The 1993 edition of this document has been approved by the American National Standards Institute.

Changes other than editorial are indicated by a vertical rule in the margin of the pages on which they appear. These lines are included as an aid to the user in identifying changes from the previous edition.

Origin and Development of NFPA 655

This standard was first presented to the Association as a progress report in 1938 by the Committee on Dust Explosion Hazards. It was tentatively adopted in 1939. After some revision, it was officially adopted in 1940. Amendments were adopted in 1946, 1947, 1959, 1968, and 1971.

In 1976, responsibility for the document was transferred to the Technical Committee on Fundamentals of Dust Explosion Prevention and Control. The Technical Committee completely revised the 1971 edition to effect minor technical amendments and to editorially revise the document to comply with the NFPA *Manual of Style*.

Due to limited technological changes in this subject area between 1982 and 1988, the Committee reconfirmed the text as it had appeared in the 1982 version. Editorial changes and changes to allow the document to adhere more closely to the NFPA Manual of Style were incorporated into the 1988 edition.

For this 1993 edition, the Committee has made minor revisions to Chapter 2 for handling finely divided sulfur in bulk and minor revisions to the fire fighting procedures to be used when fighting fires involving sulfur, as well as editorial revisions to conform to the NFPA *Manual of Style*.

Technical Committee on Fundamentals of Dust Explosion Prevention and Control

Robert W. Nelson, *Chair*
Industrial Risk Insurers, CT
Rep. Industrial Risk Insurers

John M. Cholin, J. M. Cholin Consultants Inc., NJ

C. James Dahn, Safety Consulting Engineers, Inc., IL

David C. Kirby, Union Carbide Corp., WV

James E. Maness, Bunge Corp., AR
Rep. Grain Elevator & Processing Society

Michael E. Mowrer, Professional Loss Control Inc., TN

Gary A. Page, American Cyanamid Co., NJ

James L. Roberts, Fluor Daniel, Inc., SC

Committee Scope: This Technical Committee shall have primary responsibility for documents that are generally applicable to all dusts on the fundamentals of dust explosion prevention. This Committee shall also be responsible for documents on the prevention, control, and extinguishment of fires and explosions in dust collection equipment and in pneumatic conveying equipment.

NFPA 655

Standard for

Prevention of Sulfur Fires and Explosions

1993 Edition

NOTICE: An asterisk (*) following the number or letter designating a paragraph indicates explanatory material on that paragraph in Appendix A.
Information on referenced publications can be found in Chapter 6 and Appendix B.

Chapter 1 General

1-1 Scope.

1-1.1*

This standard shall apply to the crushing, grinding, or pulverizing of sulfur and to the handling of sulfur.

1-1.2

This standard shall not apply to the mining or transportation of sulfur.

1-2 Purpose.

1-2.1

The purpose of this standard shall be to provide requirements to eliminate or reduce the hazards of explosion and fire inherent in the processing and handling of sulfur.

1-2.2

This standard shall not be intended to prevent the use of systems, methods, or devices that provide equivalent protection from fire and explosion, providing that suitable data is available to demonstrate equivalency.

1-3 Retroactivity.

This standard applies to facilities on which construction is begun subsequent to the date of publication of this standard. When major replacement or renovation of existing facilities is planned, provisions of this standard shall apply.

1-4 Definitions.

For the purpose of this standard, the following terms shall have the meanings given below.

Approved. Acceptable to the “authority having jurisdiction.”

NOTE: The National Fire Protection Association does not approve, inspect or certify any installations, procedures, equipment, or materials nor does it approve or evaluate testing laboratories. In determining the acceptability of installations or procedures, equipment or materials, the authority having jurisdiction may base acceptance on compliance with NFPA or other appropriate standards. In the absence of such standards, said authority may require evidence of proper installation, procedure or use. The authority having jurisdiction may also refer to the listings or labeling practices of an organization concerned with product evaluations which is in a position to determine compliance with appropriate standards for the current production of listed items.

Authority Having Jurisdiction. The “authority having jurisdiction” is the organization, office or individual responsible for “approving” equipment, an installation or a procedure.

NOTE: The phrase “authority having jurisdiction” is used in NFPA documents in a broad manner since jurisdictions and “approval” agencies vary as do their responsibilities. Where public safety is primary, the “authority having jurisdiction” may be a federal, state, local or other regional department or individual such as a fire chief, fire marshal, chief of a fire prevention bureau, labor department, health department, building official, electrical inspector, or others having statutory authority. For insurance purposes, an insurance inspection department, rating bureau, or other insurance company representative may be the “authority having jurisdiction.” In many circumstances the property owner or his designated agent assumes the role of the “authority having jurisdiction”; at government installations, the commanding officer or departmental official may be the “authority having jurisdiction.”

Labeled. Equipment or materials to which has been attached a label, symbol or other identifying mark of an organization acceptable to the “authority having jurisdiction” and concerned with product evaluation, that maintains periodic inspection of production of labeled equipment or materials and by whose labeling the manufacturer indicates compliance with appropriate standards or performance in a specified manner.

Listed. Equipment or materials included in a list published by an organization acceptable to the "authority having jurisdiction" and concerned with product evaluation, that maintains periodic inspection of production of listed equipment or materials and whose listing states either that the equipment or material meets appropriate standards or has been tested and found suitable for use in a specified manner.

NOTE: The means for identifying listed equipment may vary for each organization concerned with product evaluation, some of which do not recognize equipment as listed unless it is also labeled. The "authority having jurisdiction" should utilize the system employed by the listing organization to identify a listed product.

Shall. Indicates a mandatory requirement.

Should. Indicates a recommendation or that which is advised but not required.

Sulfur Dust.* Any finely divided solid sulfur that presents a fire or explosion hazard.

Chapter 2 Handling Finely Divided Sulfur in Bulk

2-1 General.

2-1.1

This chapter shall apply to the production, handling, and processing of finely divided sulfur.

2-1.2

For the purpose of this standard, machinery for crushing and pulverizing sulfur shall be grouped into the following categories:

(a) *Type 1.* Slow-speed primary crushers, such as jaw and roll crushers.

(b) *Type 2.* High-speed primary crushers, such as disk and hammer mills, pulverizers, and fine grinding equipment of all kinds, except Type 4, having a net internal volume of not more than 500 $in.^3$ (8193 cm^3).

(c) *Type 3.* Crushers and pulverizers of the Type 2 category, but having an internal volume of more than 500 $in.^3$ (8193 cm^3).

(d)* *Type 4.* Pulverizers that do not depend on moving parts for their disintegrating action, such as attrition mills.

2-1.3

Operation and maintenance of all crushing and pulverizing machinery shall be under supervision.

2-2 Location, Construction, and Venting of Buildings and Equipment.

2-2.1 Location of Crushing or Pulverizing Machinery and Containers.

2-2.1.1 The enclosed or semienclosed space in which the crushing or pulverizing machinery is located shall be used for no other purpose during the periods when size reduction of sulfur is in progress.

Exception: Containers shall be permitted to be filled with the ground product.

2-2.1.2* Containers shall be removed from the area as soon as possible after being filled. Containers shall not be allowed to accumulate in the area.

2-2.2 Building Construction Requirements for Housing Grinding or Pulverizing Machinery.

2-2.2.1* The enclosed or semienclosed space in which the grinding or pulverizing machinery is located shall be separated from other areas by noncombustible construction. The separating walls shall be designed to withstand the force of an explosion.

2-2.2.2 Openings through floors, walls, and ceilings for necessary pipes, shafts, and conveyors shall be tightly sealed. (*See 2-2.3.1.*)

2-2.3 Protection of Openings.

2-2.3.1 All communications between the space used for grinding and the rest of the building shall be from the outside or via indirect means as described below.

2-2.3.2* Indirect communications through separating walls by means of vestibules or stairways shall be permitted, provided the wall opening to the grinding area is protected by an automatic closing sliding fire door suitable for 3-hr openings, and the opening into the vestibule or stairway is protected by a hinged fire door suitable for 2-hr openings. The two doors shall be installed at right angles to each other. Both doors shall be installed in accordance with NFPA 80, *Standard for Fire Doors and Fire Windows*.

2-2.4*

Buildings housing operations that present a dust explosion hazard shall be designed with explosion venting.

2-2.5

All ledges and surfaces on which dust can accumulate shall be avoided in construction. Where such surfaces cannot be avoided, they shall be filled in or roofed with noncombustible material at an angle of not less than 45 degrees.

2-2.6

Explosion prevention or protection shall be provided on all equipment. One of the following methods shall be used:

(a) Equipment can be designed to contain the anticipated explosion pressure.

(b)* Appropriately designed explosion venting can be provided.

(c) An explosion suppression system meeting the requirements of NFPA 69, *Standard on Explosion Prevention Systems*, can be provided.

(d) Inert gas can be used to reduce the oxygen content within the equipment to below the level prescribed by NFPA 69, *Standard on Explosion Prevention Systems*.

2-3* Electrical Wiring and Equipment.

All electrical wiring and equipment shall comply with NFPA 70, *National Electrical Code*®. In areas where a dust explosion hazard exists, electrical wiring and equipment shall comply with Article 502 of NFPA 70.

2-4 Inert Gas.

2-4.1

Use of inert gas is not required for Type 1 machinery.

2-4.2

Type 2 machinery shall be permitted to be operated without inert gas protection if the following requirements are met:

(a) The feed and discharge shall be provided with positive chokes, such as a star feed rotary valve or a screw conveyor with the end flights removed, where directly connected to the machine.

(b) The chokes and all machinery between shall be capable of withstanding an overpressure of 100 lb per in.^{2} (690 kPa).

(c) There shall be an inspection of the machinery at least once per shift during operation to detect abnormalities in operating conditions.

2-4.3

Type 3 machinery shall not be operated without the use of an inert gas system meeting the requirements of NFPA 69, *Standard on Explosion Prevention Systems*. Where the pulverized sulfur is removed from the machinery by blower or exhaust systems, inert gas protection shall extend to all piping and collectors.

2-4.3.1 Under normal operating conditions, the reduction in oxygen content shall be to 12 percent for carbon dioxide systems and to 9.3 percent for nitrogen systems.

2-4.3.2* The inert gas system shall be equipped with sampling and recording instruments to obtain a reliable and continuous analysis of the inert atmosphere in that part or parts of the machinery where the inert atmosphere is normally weakest.

2-4.3.3 Provisions shall be made for automatically shutting down the pulverizing machinery if the oxygen content of the inert atmosphere rises above the maximum levels stated in 2-4.3.1.

2-4.4*

Type 4 machinery shall be permitted to be operated without inert gas protection if the following requirements are met:

(a) Manually operated valves shall be installed at each machine for control of feed and air lines.

(b)* The equipment shall be under supervision during operation and shall be shut down for detailed inspection and any necessary cleaning when abnormalities in operation indicate the possibility of fire within the machine.

(c) All valves shall be closed before opening the machine.

2-4.5

Auxiliary dust collectors shall be installed according to the requirements of 2-5.5.

2-5 Conveyors and Collectors.

2-5.1

Only conveyors or spouts with positive seals, such as star feed rotary valves or screw conveyors with the end flights removed, shall be permitted to pass through a fire partition separating crushing or pulverizing rooms from adjacent spaces. The chokes or seals shall be located so as to prevent flame propagation through the wall.

2-5.2

Conveyors used to feed or discharge sulfur to or from grinding machinery shall be in dusttight housings.

2-5.3

Nonferrous buckets or bucket elevators shall be used where they are housed in ferrous casings.

Exception: In cases where the above requirement is not met, steam shall be blown into the elevator boot while the elevator is in operation or an inert gas system meeting the requirements of 2-4.3 shall be used.

2-5.4

Pneumatic conveying systems shall be designed in accordance with NFPA 650, *Standard for Pneumatic Conveying Systems for Handling Combustible Materials*. Each pulverizer shall have a separate and self-contained system.

2-5.5 Dust Collection Systems.

2-5.5.1 Where dust collectors are not protected according to 2-2.6, they shall be isolated in any of the following locations:

(a) On the roof,

(b) Outside and adequately detached from buildings,

(c) In separate rooms provided with explosion venting,

(d) In separate buildings provided with explosion venting,

(e) In isolated penthouses provided with explosion venting.

2-5.5.2 Manifolding of ducts serving dust collection systems shall not be permitted.

Exception No. 1: Dust collection ducts from a single piece of equipment or from multiple pieces of equipment that are not isolated from each other need not be manifolded.
Exception No. 2: Dust collection ducts from single, isolated pieces of equipment shall be permitted to be manifolded if each duct is equipped with a suitable isolation device prior to manifolding. (See NFPA 69, Standard on Explosion Prevention Systems.)

2-5.5.3 Dust collectors shall be constructed of noncombustible materials.

Exception: Filter media need not be of noncombustible material if provided with tight metal enclosures or their equivalent.

2-5.5.4 Recycling of air from dust collectors back to buildings shall not be permitted.

2-6 Prevention of Ignition.

2-6.1*

Approved magnetic separators of the permanent magnet or self-cleaning electromagnetic types or approved pneumatic separators shall be installed ahead of all Types 2, 3, and 4 machines. The installation shall be designed to ensure removal of all ferrous material from the sulfur.

2-6.2

All machinery shall be installed and maintained in such a manner that the possibility of frictional sparks is minimized.

2-6.3

Interlocking controls shall be installed to stop the dust feed if the pulverizer stops or if the fans or blowers stop for any reason.

2-6.4*

All machinery, conveyors, housings, and collectors shall be thoroughly bonded and grounded to prevent the accumulation of static electricity.

2-6.5

All open flames, smoking, and matches shall be prohibited in enclosures containing crushers and pulverizers. Unprotected hot surfaces, such as steam lines, that can attain temperatures high enough to melt and ignite sulfur dust shall not be exposed in enclosures housing sulfur processing equipment.

Exception: Repairs involving open flames, such as cutting or welding, heat, or hand or power tools, shall be made only after all operations have ceased and all sulfur has been removed from the vicinity or protected in tight noncombustible containers. Cutting and welding procedures shall be carried out according to the requirements of NFPA 51B, Standard for Fire Prevention in Use of Cutting and Welding Processes.

2-6.6 Powder-Operated Tools.

2-6.6.1 Powder-operated tools shall not be used where combustible dust or dust clouds are present. When the use of such tools becomes necessary, all dust-producing machinery in the area shall be shut down, all equipment, floors, and walls shall be cleaned thoroughly, and all accumulations of dust removed.

2-6.6.2 After such work has been completed, a check shall be made to ensure that no cartridges or charges have been left on the premises where they could enter equipment or be accidently discharged after operation of the dust-producing or dust-handling machinery is resumed.

2-7 Housekeeping.

2-7.1*

Good housekeeping is of utmost importance. Equipment shall be designed, maintained, and operated in a manner that will minimize the escape of dust. Accumulations of escaped dust shall not be tolerated in the buildings.

2-7.2*

Bulk accumulations of fine sulfur shall be removed by soft push brooms and nonsparking scoops or shovels before vacuum cleaning equipment is used.

2-7.3

Cleaning shall be permitted to be done by vacuum sweeping devices. If vacuum apparatus is used, either stationary or portable types shall be properly grounded and checked for electrical continuity from pickup nozzle to piping system. Such equipment, if electrical, shall be of a class approved for use in atmospheres containing sulfur dust. (*See Section 2-3.*)

2-7.4

Blowing down of any surfaces by compressed air shall be prohibited.

2-8 Fire Fighting.

2-8.1*

Fog nozzles shall be used when fighting fires in finely divided sulfur.

2-8.2*

Steam and inert gases can be used as extinguishing agents for tightly closed containers provided that the sulfur dust is not disturbed.

2-8.3

In all cases, it shall be made certain that the fire is completely extinguished before disturbing the dust and that the sulfur has cooled sufficiently to prevent reignition.

2-8.4*

When grinding or other processing equipment is opened for cleaning following an ignition, the feed, discharge, and other openings shall first be closed by suitable metal valves or gates.

2-8.5*

At least two self-contained breathing apparatus shall be made available for use in case of sulfur fires. All respiratory equipment shall be inspected at regular intervals and kept in working order at all times.

Chapter 3 Handling Coarse Sizes of Sulfur in Bulk

3-1* Handling in the Open or in Semienclosed Spaces.

3-1.1*

Conveying machinery shall be bonded and grounded to prevent the accumulation of static electricity.

3-1.2

Flames, smoking, and matches shall be prohibited in such areas. Cutting and welding operations shall be permitted for repair work, provided due precautions are taken against ignition of dust. (*See NFPA 51, Standard for the Design and Installation of Oxygen-Fuel Gas Systems for Welding, Cutting, and Allied Processes.*)

3-2 Handling in Enclosed Spaces.

3-2.1

Handling of bulk sulfur in enclosed spaces shall be done in such a manner that the formation of dust clouds is minimized.

3-2.2*

All enclosures shall be constructed of noncombustible materials and designed so that ledges on which dust can settle are minimized. Where such surfaces are unavoidable, they shall be roofed at a steep angle.

3-2.3

Where sulfur is transferred or dumped from one container to another, dusttight housings with sufficient inward air movement to prevent escape of dust shall be provided. Where mechanical exhaust systems are used to provide this air movement, the systems shall comply with NFPA 91, *Standard for Exhaust Systems for Air Conveying of Materials*.

3-2.4* Handling Sulfur in Elevators and Conveyors.

3-2.4.1 All elevators and conveyors that agitate the sulfur being transported, such as screw conveyors and bucket elevators, shall be enclosed in dusttight casings and shall be equipped with explosion venting.

3-2.4.2 Where bucket elevators are housed in ferrous casings, the buckets or bucket conveyors shall be nonferrous.

Exception: In cases where this is impractical, steam shall be blown into the elevator boot while the elevator is in operation or the elevator shall be protected by an inert gas system.

3-2.5*

All metal parts of machinery, casings, bins, and spouts shall be bonded and grounded to prevent the accumulation of static electricity.

3-2.6

All electrical wiring and equipment installed in locations classified as Class II shall comply with Article 502 of NFPA 70, *National Electrical Code.*

3-2.7

All open flames, smoking, and matches shall be prohibited within enclosures where sulfur is handled. Heating shall be by indirect means. Exposed hot surfaces, such as steam lines, shall be avoided within the enclosure.

3-2.8

Care shall be taken to minimize static or settled dust within enclosures and semienclosures. Accumulations of static dust shall be removed promptly and in such a manner as to prevent formation of dust clouds.

3-2.9

Repairs involving the use of flames, heat, or hand or power tools shall be made only after all operations have ceased. Where practical, all sulfur shall be removed or protected in tight containers. Where this is not practical, the sulfur shall be wet down and a hose line with spray nozzle provided.

3-2.10

Powder-operated tools shall not be used unless all dust-producing machinery is shut down, and all equipment, floors, and walls have been carefully cleaned. All bulk sulfur piles or dust accumulations shall be removed or thoroughly wet down. A careful check shall be made to ensure that no cartridges or charges have been left on the premises where they could enter equipment or be accidentally discharged after operation of the dust-producing or dust-handling machinery is resumed.

3-3* Fire Fighting.

3-3.l Fires in enclosures shall be fought according to the provisions of Section 2-8. Since bulk sulfur contains only a small proportion of fines, coarser hose streams shall be permitted to be used.

3-3.2

Incipient fires in storage piles can be smothered by gently shoveling sulfur onto them.

Chapter 4 Handling of Liquid Sulfur at Normal Handling Temperatures

4-1* General.

This chapter applies to the handling of liquid sulfur in the temperature range of 246°F to 309°F (119°C to 154°C).

4-2 Detection of Unsafe Conditions.

4-2.1*

Devices for measuring the concentration of combustible gas in the atmosphere over liquid sulfur shall be designed for operation in atmospheres containing hydrogen sulfide. Instruments used for detecting explosive atmospheres shall be capable of measuring the lower explosive limit of hydrogen sulfide, since it is the primary gas evolved from sulfur that can contribute to an explosive atmosphere.

4-2.2

Operations shall be discontinued whenever instruments show a combustible gas concentration of 35 percent or more of the lower explosive limit in the gas space of liquid sulfur containers. Operations shall not be resumed until the instruments indicate a concentration of 15 percent or less of the lower explosive limit.

4-3 Operating Precautions and Equipment Design.

4-3.1

The use of open flames, electric spark-producing equipment, and smoking materials shall be prohibited in the vicinity of liquid sulfur containers.

4-3.2

Liquid sulfur storage tanks shall be designed with fill lines that extend to near the tank bottom so that the incoming sulfur enters the tank below the surface of the sulfur in the tank, thereby minimizing agitation and release of hydrogen sulfide.

4-3.3

Covered storage tanks shall be provided with heated vent systems to provide natural venting of hydrogen sulfide. Vent systems shall be maintained at a temperature above the melting temperature of sulfur.

4-3.4*

Sulfur lines and storage tanks shall be bonded and grounded to prevent accumulation of static electricity. Grounding connections shall be provided for the bonding of liquid sulfur tanks and tank cars being loaded or unloaded.

4-3.5*

In pits used for melting sulfur and in liquid storage tanks, the liquid level shall not be permitted to expose the heating coils. The liquid level shall always cover the heating coils in pits used for melting sulfur.

4-4 Fire Fighting.

4-4.1*

Covered liquid sulfur tanks shall be provided with a steam extinguishing system or an inert gas system in accordance with NFPA 86, *Standard for Ovens and Furnaces*, and NFPA 69, *Standard on Explosion Prevention Systems*.

Exception: Where liquid sulfur containers can be rapidly sealed to exclude air, the SO_2 *produced will smother the fire. In such cases, steam extinguishing systems or inert gas systems shall not be required. The system shall be allowed to cool below 309°F (154°C) before recpening.*

4-4.2*

Where a fixed inerting system is used, thin corrosion-resistant rupture discs shall be placed over the inerting nozzles so that sulfur cannot condense within the nozzle.

4-4.3

Liquid sulfur stored in open containers shall be permitted to be extinguished with a fine water spray. Use of high-pressure hose streams shall be avoided. Quantity of water used shall be kept to a minimum.

Chapter 5 Handling of Liquid Sulfur and Sulfur Vapor at Temperatures above 309°F (154°C)

5-1 General.

5-1.1

This chapter shall apply to liquid sulfur and its vapors when heated in closed containers to temperatures above 309°F (154°C).

5-1.2

The requirements of Chapter 4 shall apply.

5-2 Operating Precautions and Equipment Design.

5-2.1

Equipment shall be designed to be closed as tightly as possible to prevent escape of vapor and to exclude air from the system during operation.

5-2.2

Process equipment shall be provided with adequate explosion rupture discs. The rupture discs shall relieve into vent pipes or ducts that lead directly to the outside of the building or away from the process equipment. The vent pipes or ducts shall be heated to prevent condensation of sulfur vapor.

5-2.3

An adequate supply of a suitable inerting agent such as steam shall be available at all times for blanketing and purging equipment.

5-2.4

All buildings or enclosures for such processes shall be of noncombustible construction.

5-2.5*

All electrical wiring and equipment installed in areas handling liquid sulfur shall meet the requirements of Article 501 of NFPA 70, *National Electrical Code*.

5-2.6

Where sulfur is vaporized and subsequently condensed to sulfur dust, handling of the finely divided sulfur from the process shall comply with the requirements of Chapter 2.

Chapter 6 Referenced Publications

6-1

The following documents or portions thereof are referenced within this standard and shall be considered part of the requirements of this document. The edition indicated for each reference is the current edition as of the date of the NFPA issuance of this document.

6-1.1 NFPA Publications.

National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.

NFPA 51B, *Standard for Fire Prevention in Use of Cutting and Welding Processes*, 1989 edition.

NFPA 69, *Standard on Explosion Prevention Systems*, 1992 edition.

NFPA 70, *National Electrical Code*, 1993 edition.

NFPA 80, *Standard for Fire Doors and Fire Windows*, 1992 edition.

NFPA 86, *Standard for Ovens and Furnaces*, 1990 edition.

NFPA 91, *Standard for Exhaust Systems for Air Conveying of Materials*, 1992 edition.

NFPA 650, *Standard for Pneumatic Conveying Systems for Handling Combustible Materials*, 1990 editiion.

Appendix A Explanatory Material

This Appendix is not a part of the requirements of this NFPA standard, but is included for information purposes only.

A-1-1.1

Sulfur differs from most other combustible dusts found in industry in that it has relatively low melting and ignition points. Depending on purity, sulfur melts at or slightly below 246°F (119°C). The ignition temperature of a dust cloud is 374°F (190°C); the ignition temperature of a dust layer is 428°F (220°C). Dilution of sulfur with inert solids is not effective in raising the ignition temperature.

Sulfur is handled and processed in the liquid and vapor states in some cases. The liquid is highly combustible and the vapor is explosive when mixed with air in the proper proportions.

The finely divided sulfur produced during crushing and pulverizing is the most hazardous from an explosion standpoint. Also, mixtures containing finely divided elemental sulfur may be just as hazardous if the sulfur is present in sufficient quantity. Some explosion and fire hazards also accompany the handling and processing of sulfur in bulk in coarse sizes due to the fine dust present.

A-1-4 Sulfur Dust

The Committee is aware of data contained in R. K. Eckhoff's book *Dust Explosions in the Process Industries*, Table A1, pg. 582, which reported positive explosion test results of a sulfur dust cloud with a median particle size of 120 microns as being explosible.

A-2-1.2 (d) The grinding in Type 4 machines is accomplished by attrition of the particles on themselves. Power for moving the particles is furnished by compressed air or other fluid suitable to the material being pulverized.

A-2-2.1.2 It is not the intent of this requirement to prohibit interim storage of bags, drums, or filled containers.

A-2-2.2.1 The grinding space should preferably be detached. Exterior walls may have to be provided with explosion venting. Steel frame construction, with light, nonbearing exterior walls and light roof, is preferable.

A-2-2.3.2 It is recommended that an emergency escapeway for personnel be provided independently.

A-2-2.4

See NFPA 68, *Guide for Venting of Deflagrations.*

A-2-2.6 (b) See NFPA 68, *Guide for Venting of Deflagrations*, for design information on the subject.

A-2-3

Although sulfur is not now included in atmospheres classified as Class II, Group G, it has been the experience of the sulfur industry that such equipment can be suitable. However, consideration should be given to the melting point of sulfur 233°F to 246°F (112°C to 119°C) in the selection of heat-producing electrical equipment.

A-2-4.3.2 Auxiliary instrumentation should be provided for sampling and recording the quality of the inert atmosphere in other parts of the system.

A-2-4.4

The large volumes and high velocities of air and the compactness of the Type 4 unit make inerting usually impractical.

A-2-4.4 (b) Flooding with inert gas or steam, combined with delayed opening to permit smothering of any residual fire, is recommended.

A-2-6.1

It must be recognized that magnetic separators will not remove nonferrous tramp material, including stones, brick, and concrete. Every care, using other means, should be taken to ensure excluding such materials from the grinding system.

A-2-6.4

See NFPA 77, *Recommended Practice on Static Electricity*, for information on the subject.

A-2-7.1

It is recommended that the interior of crushing, pulverizing, and packaging rooms or buildings be painted a color that contrasts with the color of the dust.

A-2-7.2

Push brooms should have natural bristles.

A-2-8.1

Straight streams from hoses or extinguishers should not be used, as a cloud of dust can be raised that will explode on contact with the fire.

A-2-8.2

If a container is closed tightly and the volume of oxygen enclosed is not too large, a fire will be smothered by the sulfur dioxide formed.

A-2-8.4

A period of at least 15 minutes should elapse between closing the valves or gates and opening the equipment to smother any residual fire in the equipment. As an added precaution, the equipment should be flooded with inert gas or steam, if available, prior to opening.

A-2-8.5

Gas masks approved for acid gases will not provide adequate protection in a serious sulfur fire. Self-contained breathing apparatus of the pressure demand type should be used.

A-3-1

Clouds of fine sulfur dust arising during the handling of bulk sulfur in the open or in semienclosed spaces are potentially dangerous. Arrangements should be such that they will not contact sources of ignition.

A-3-1.1

See NFPA 77, *Recommended Practice on Static Electricity*, for information on the subject.

A-3-2.2

Direct ventilation of enclosed spaces is recommended.

A-3-2.4

See NFPA 68, *Guide for Venting of Deflagrations*, for information on the subject.

A-3-2.5

See NFPA 77, *Recommended Practice on Static Electricity*, for information on the subject.

A-3-3

Automatic sprinkler protection is recommended for enclosures in which sulfur is stored or handled.

A-4-1

The normal handling temperature of liquid sulfur is 250°F to 309°F (121°C to 154°C), which is slightly above the melting point of 246°F (119°C). At this temperature, the vapor concentration above pure sulfur, free of hydrocarbons or hydrogen sulfide, is too low to form an explosive mixture in air. While the flash point of liquid sulfur varies with purity, it is always higher than the normal handling temperature. For pure sulfur, the flash point is about 370°F (188°C); for relatively impure crude sulfur, the flash point may be as low as 334°F (168°C).

The relatively low ignition temperature of sulfur and the possible presence of hydrogen sulfide are the primary fire and explosion hazards of liquid sulfur. Impure sulfur contains hydrocarbons, which react slowly with liquid sulfur to form hydrogen sulfide. Recovered sulfurs, such as those produced from hydrogen, often contain dissolved hydrogen sulfide. Hydrogen sulfide is quite soluble in liquid sulfur and will be liberated very slowly from a quiescent body of liquid sulfur. However, agitation of the sulfur can cause rapid evolution of hydrogen sulfide, which may create an explosive atmosphere within a storage tank. (In the temperature range at which liquid sulfur is normally handled, the lower explosive limit for hydrogen sulfide in air is about 3.4 percent, compared to 4.3 percent at room temperature.)

Pure sulfur will not generate an explosive atmosphere in the normal temperature range of the liquid.

A-4-2.1

The sensing elements of some explosimeters are not designed for and are adversely affected by hydrogen sulfide-containing atmospheres.

A-4-3.4

See NFPA 77, *Recommended Practice on Static Electricity*, for information on the subject.

A-4-3.5

Pyrophoric iron sulfide compounds may form from impurities in the sulfur. When heating coils are exposed to air, ignition may occur.

A-4-4.1

The inert gas must be applied rapidly enough to displace the ventilation air from the vents. Steam may be generated through the application of water through fog nozzles. Open vents should be available to prevent the buildup of steam pressure.

A-4-4.2

Sulfur flour may cause a dust explosion if it is ejected from the nozzles ahead of the inerting agent.

A-5-2.5

Due to the potential for release of dissolved hydrogen sulfide, molten sulfur handling systems require a Class I, Group C, classification for confined areas.

Appendix B Referenced Publications

B-1

The following documents or portions thereof are referenced within this standard for informational purposes only and thus should not be considered part of the requirements of this document. The edition indicated for each reference is the current edition as of the date of the NFPA issuance of this document.

B-1.1 NFPA Publications.

National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.

NFPA 51, *Standard for the Design and Installation of Oxygen-Fuel Gas Systems for Welding, Cutting, and Allied Processes*, 1992 edition.

NFPA 68, *Guide for Venting of Deflagrations*, 1988 edition.

NFPA 69, *Standard on Explosion Prevention Systems*, 1992 edition.

NFPA 77, *Recommended Practice on Static Electricity*, 1993 edition.

B-1.2 Other Publications.

Eckhoff, R. K., *Dust Explosions in the Process Industries*, Oxford, England:Butterworth-Heinemann Ltd., 1991.

NFPA 664

1993 Edition

Standard for the Prevention of Fires and Explosions in Wood Processing and Woodworking Facilities

1993 Edition

This edition of NFPA 664, *Standard for the Prevention of Fires and Explosions in Wood Processing and Woodworking Facilities*, was prepared by the Technical Committee on Wood, Paper and Cellulosic Dusts and acted on by the National Fire Protection Association, Inc. at its

Annual Meeting held May 24-27, 1993, in Orlando, FL. It was issued by the Standards Council on July 23, 1993, with an effective date of August 20, 1993, and supersedes all previous editions.

The 1993 edition of this document has been approved by the American National Standards Institute.

Changes other than editorial are indicated by a vertical rule in the margin of the pages on which they appear. These lines are included as an aid to the user in identifying changes from the previous edition.

Origin and Development of NFPA 664

NFPA activity in the field of wood dust explosion hazards dates from 1930, when work on a *Code on Wood Flour Manufacturing* (No. 662) was initiated. The first edition was adopted in 1931, and subsequent editions were issued in 1940, 1942, 1946, and 1949. A separate *Code on Woodworking Plants* (No. 663) was added in 1934, and reissued in 1952 and 1959. In 1960 these two codes were combined in a new *Code for the Prevention of Dust Explosions in Woodworking and Wood Flour Manufacturing Plants* (No. 664), and revised editions were adopted in 1962 and 1971. The 1981 edition of the standard consisted of a complete rewrite. The 1987 edition clarified the intent of numerous existing requirements. A new chapter which covered thermal oil heating systems was added as a result of increased use of these systems in industry. The format of the 1987 revision was to conform with the NFPA *Manual of Style*.

For this 1993 edition, the Committee has provided information on the characteristics of wood dust covered by the standard, clarified the dust collection requirements including the provisions for recycling exhaust air, and incorporated minor editorial revisions to comply with the NFPA *Manual of Style*.

Technical Committee on Wood, Paper and Cellulosic Dusts

Peter H. Billing, Nat'l Forest Products Assn., FL

Byron G. Bombay, KraftMaid Cabinetry (Masco Inc.), OH

Kenneth W. Dungan, Professional Loss Control Inc., TN

Thomas E. Frank, Factory Mutual Engr Assn., WA

James M. Ingalls, Industrial Risk Insurers, CT
(Rep. Industrial Risk Insurers)

Lowell E. Pauli, Lowell E. Pauli & Assoc. Inc., OR

C. Curtis Peterson, American Hardboard Assn., IL

Glyn H. Stock, 3S, Inc., OH

Alternates

Committee Scope: Responsible for documents for the prevention, control, and extinguishment of fires and explosions resulting from dusts produced from the handling, processing, or storage of wood and paper and other cellulosic materials.

NFPA 664
Standard for the Prevention of Fires and Explosions in Wood Processing and Woodworking Facilities

1993 Edition

NOTICE: An asterisk (*) following the number or letter designating a paragraph indicates explanatory material on that paragraph in Appendix A.
Information on referenced publications can be found in Chapter 12 and Appendix B.

Chapter 1 General

1-1 Scope.

1-1.1*

This standard contains the minimum requirements for the proper construction and protection of facilities that handle, store, or process wood, or wood products that produce or utilize finely divided wood particles or wood fibers.

1-1.2*

This standard shall apply to production or industrial-scale woodworking operations.

Exception: It does not apply to small-scale woodworking operations that are incidental to the principal occupancy.

1-2 Purpose.

1-2.1

The purpose of this standard is to provide a reasonable degree of protection for life and property against fire and explosion in facilities where finely divided wood dust is produced or handled.

1-2.2 Equivalency.

Nothing in this standard is intended to prevent the use of systems, methods, or devices of equivalent or superior quality, strength, fire resistance, effectiveness, durability, and safety over those prescribed by this standard, provided technical documentation is submitted to the authority having jurisdiction to demonstrate equivalency and the system, method, or device is approved for the intended purpose.

1-3* Retroactivity.

This standard shall apply to new facilities and to those portions of existing facilities being rebuilt or remodeled.

1-4 Definitions.

Approved.* Acceptable to the “authority having jurisdiction.”

Authority Having Jurisdiction.* The “authority having jurisdiction” is the organization, office or individual responsible for “approving” equipment, an installation or a procedure.

Labeled. Equipment or materials to which has been attached a label, symbol or other identifying mark of an organization acceptable to the “authority having jurisdiction” and concerned with product evaluation, that maintains periodic inspection of production of labeled equipment or materials and by whose labeling the manufacturer indicates compliance with appropriate standards or performance in a specified manner.

Listed.* Equipment or materials included in a list published by an organization acceptable to the “authority having jurisdiction” and concerned with product evaluation, that maintains periodic inspection of production of listed equipment or materials and whose listing states either that the equipment or material meets appropriate standards or has been tested and found suitable for use in a specified manner.

Shall. Indicates a mandatory requirement.

Should. Indicates a recommendation or that which is advised but not required.

Standard. A document containing only mandatory provisions using the word “shall” to indicate requirements. Explanatory material may be included only in the form of “fine print” notes, in footnotes, or in an appendix.

Chapter 2 Building Construction

2-1 General Requirements.

2-1.1*

The construction features of this chapter shall apply in addition to those required by state or local building codes.

2-1.2*

Precautions shall be taken to prevent the spread of fire from one section of the plant to another. These precautions shall include separation of adjacent buildings by open space or adjoining buildings by fire walls or fire partitions, as well as elimination of all unnecessary openings through floors.

2-2 Wall Construction.

2-2.1

Where walls are erected as fire walls between adjoining buildings, they shall be designed for a minimum fire endurance of four hours.

2-2.2

Interior walls erected as fire partitions between adjoining areas shall be designed for a minimum fire endurance of one hour.

2-2.3*

Interior walls erected to isolate dust explosion hazards shall be designed for sufficient explosion resistance to preclude damage to these walls before the explosion pressure can be safely vented to the outside.

2-3 Protection of Wall Openings.

2-3.1

Openings in fire partitions shall be protected by approved automatic closing fire doors having a fire endurance rating equivalent to the fire endurance rating of the fire partition. Fire doors shall be installed according to NFPA 80, *Standard for Fire Doors and Fire Windows*.

2-3.2

Openings in four-hour rated fire walls shall be protected by three-hour rated automatic closing fire doors installed on both sides of the wall.

2-3.3

All pipe openings through fire walls and fire partitions shall be tight. All duct openings through fire partitions shall be protected by approved fire dampers. No ducts shall penetrate fire walls.

2-3.4*

Openings in walls designed to be explosion resistant shall be protected by doors that provide the same degree of explosion protection as the walls. Such doors shall be kept closed at all times when not actually being used. Such doors shall not be considered as part of a means of egress to satisfy the requirements of NFPA *101*®, *Life Safety Code*®.

2-4 Stairways, Elevators, and Fire Escapes.

Exits, interior stairs, and elevators shall comply with *NFPA 101*, *Life Safety Code*.

2-5 Surfaces and Ledges in Dusty Areas.

2-5.1

Interior surfaces and ledges shall be designed to minimize dust accumulation.

2-5.2*

Surfaces not readily accessible for cleaning shall be inclined at an angle of not less than 45 degrees from the horizontal to minimize dust accumulation.

Chapter 3 Explosion Venting

3-1* General Requirements.

3-1.1*

Explosion venting, as used in this standard, is intended to encompass the design and installation of devices and systems to vent the gases and overpressure resulting from a deflagration so as to minimize structural or mechanical damage to the equipment, room, building, or other enclosure in which the explosion occurs.

3-1.2*

If a dust explosion hazard exists in equipment, rooms, buildings, or other enclosures, such areas shall be provided with explosion venting. An acceptable alternative to explosion venting is an approved explosion suppression system installed in accordance with NFPA 69, *Standard on Explosion Prevention Systems*.

Chapter 4 Housekeeping

4-1 Removal of Static Dust.

4-1.1

Provisions shall be made for systematic, thorough cleaning of the entire plant at sufficient intervals to prevent the accumulations of finely divided wood dust that might be dislodged and lead to an explosion.

4-1.2

Spills shall be cleaned up without delay.

4-1.3*

Powered cleaning apparatus, such as sweepers or vacuum cleaning equipment, used in dusty areas shall be approved for Class II, Division 1, Group G locations as defined in Article 502 of NFPA 70, *National Electrical Code®*.

4-1.4*

The use of compressed air or other similar means to remove dust accumulations from areas not readily accessible for cleaning by other methods shall be permitted only if done frequently enough to prevent hazardous concentrations of dust in suspension. Any open flame or spark-producing equipment shall not be used during blowdown.

4-2 Metal Scrap.

Provisions shall be made for separately collecting and disposing of any metal scrap, such as nails, band iron, or any wood containing metal, so that it will not enter the wood handling or processing equipment, the dust collecting system, or the scrap wood hog.

4-3* Hydraulic Fluids.

Combustible hydraulic fluid leaks, especially in press areas, shall be controlled by regular maintenance. Spilled fluid shall be cleaned up promptly.

4-4 Oil and Resin.

Buildup of residue from condensation of oil and resin volatiles shall be removed from board curing ovens at regular intervals.

4-5 Flammable Liquids.

Flammable liquids shall be handled and stored according to the requirements of NFPA 30, *Flammable and Combustible Liquids Code*.

Chapter 5 Electrical Equipment

5-1 Electrical Wiring and Equipment.

5-1.1

All electrical wiring and equipment shall comply with the requirements of NFPA 70, *National Electrical Code*.

5-1.2*

In local areas of the plant where a hazardous quantity of dust accumulates or is present in suspension in the air, all electrical equipment and installations in those local areas shall comply with Article 502 or Article 503 of NFPA 70, *National Electrical Code*, as applicable.

Chapter 6 Control of Ignition Sources

6-1 Cutting and Welding.

Cutting and welding shall comply with applicable requirements of NFPA 51B, *Standard for Fire Prevention in Use of Cutting and Welding Processes*.

6-2 Static Electricity and Lightning Protection.

6-2.1*

Static electricity shall be prevented from accumulating on machines or equipment subject to static electricity buildup by permanent grounding and bonding wires and from moving belts by grounded metal combs or other effective means.

6-2.2

Lightning protection, where required, shall be installed in accordance with NFPA 780, *Lightning Protection Code*.

6-3 Smoking.

Smoking shall only be allowed in safe designated areas.

6-4 Propellant-Actuated Tools.

6-4.1

Propellant-actuated tools shall not be used in areas where combustible dust or dust clouds are present.

6-4.2

When the use of propellant-actuated tools becomes necessary, all dust-producing machinery in the area shall be shut down; all equipment, floors, and walls shall be carefully cleaned; and all dust accumulations removed.

6-4.3

A careful check shall be made after the work is completed to ensure that no cartridges or charges are left on the premises where they could enter equipment or be accidentally discharged after operation of the dust-producing or handling machinery is resumed.

Chapter 7 Fire Protection

7-1 Fire Extinguishers and Hose.

7-1.1

Portable fire extinguishers shall be provided throughout all buildings in accordance with the requirements of NFPA 10, *Standard for Portable Fire Extinguishers*.

7-1.2*

Standpipes and hose, where provided, shall conform to NFPA 14, *Standard for the Installation of Standpipe and Hose Systems*.

7-1.3

Private outside protection, including outside hydrants and hoses, where provided, shall comply with NFPA 24, *Standard for the Installation of Private Fire Service Mains and Their Appurtenances*.

7-2* Automatic Sprinklers.

Automatic sprinklers, where provided, shall comply with NFPA 13, *Standard for the Installation of Sprinkler Systems*.

7-3 Special Fire Protection Systems.

Automatic extinguishing systems or special hazard extinguishing systems, where provided, shall be designed, installed, and maintained in accordance with the following standards, as applicable:

(a) NFPA 11, *Standard for Low Expansion Foam and Combined Agent Systems*

(b) NFPA 11A, *Standard for Medium- and High-Expansion Foam Systems*

(c) NFPA 12, *Standard on Carbon Dioxide Extinguishing Systems*

(d) NFPA 12A, *Standard on Halon 1301 Fire Extinguishing Systems*

(e) NFPA 12B, *Standard on Halon 1211 Fire Extinguishing Systems*

(f) NFPA 15, *Standard for Water Spray Fixed Systems for Fire Protection*

(g) NFPA 17, *Standard for Dry Chemical Extinguishing Systems*

(h) NFPA 69, *Standard on Explosion Prevention Systems*

Chapter 8 Woodworking Dust-Control Systems

8-1 Scope.

This chapter shall apply to pneumatic systems utilized to collect and convey finely divided wood particles, fibers, or shavings in the course of woodworking operations.

8-2 Conveying and Collecting Equipment.

8-2.1*

Dust collection systems shall comply with the requirements of NFPA 91, *Standard for Exhaust Systems for Air Conveying of Materials*.

8-2.2*

Dust collectors shall be located outside of buildings.

Exception No. 1: Dust collectors shall be permitted to be located inside of buildings if they are located adjacent to an exterior wall, are vented to the outside through straight ducts not exceeding 10 ft (3 m) in length, and have explosion vents.*

Exception No. 2: Dust collectors shall be permitted to be located inside of buildings if protected by an explosion suppression system meeting the requirements of NFPA 69, Standard on Explosion Prevention Systems.

8-2.3

All cutting, shaping, planing, sanding, or other machines that produce finely divided wood dust or shavings shall be provided with a dust pickup, conveying, and collecting system.

8-2.4 Hoods and Enclosures.

8-2.4.1 Hoods or enclosures shall be so designed, located, and placed that the finely divided wood dust or shavings generated will fall, be projected, or be drawn into the hood or enclosures in the direction of the airflow and to provide the greatest possible enclosure in the zone of wood particle generation without interfering with the safe and satisfactory operation of the machine.

8-2.4.2 All hoods and enclosures shall be of noncombustible construction. If the hood or enclosure also must act as a safety guard, the construction, strength, and material specifications must be such that the machine is adequately protected.

8-2.4.3 The rate of airflow into every hood and enclosure shall be sufficient to control the wood dust or shavings and cause them to be carried into the duct system.

8-2.5 Duct System.

8-2.5.1 Every branch duct and every section of main duct shall be sized for not less than the minimum air velocity and volume required to transport the wood dust or shavings through the ducting and into the collection equipment.

8-2.5.2 The capacity of the system shall be calculated on the basis of all hoods and other openings connected to the system being open.

8-2.5.3 Dampers, gates, or orifice plates provided for the specific purpose of balancing the airflow in the system shall be fastened to prevent inadvertent manipulation.

8-2.5.4 In addition to the intakes at the individual machines, connections to the system shall be permitted at floor level in convenient locations to provide for the removal of such fine material that accumulates around the machines and be swept up.

8-2.6 Collecting Equipment.

The system shall be provided with collecting equipment of sufficient size and capacity to separate the wood dust from the air before the air is vented. The collecting equipment shall be of noncombustible construction except for filter bags, if provided.

8-2.7 Fans or Blowers.

The system shall be connected to a fan or blower that will maintain the required rate of airflow in all parts of the system and is of a type and size suitable for handling the conveyed material. Where conditions permit, the fan shall be located beyond the air cleaning equipment to handle only cleaned air.

8-2.8 Exhausting Dissimilar Matter.

Woodworking exhaust systems shall be restricted to handling wood residues and under no circumstances shall another operation generating sparks, such as from grinding wheels, be connected to a woodworking exhaust system.

8-3 Hazardous Systems.

8-3.1*

The additional requirements of this section shall apply to systems that handle finely divided wood dust with an explosion potential.

8-3.2

All hoods and enclosures shall be constructed of welded steel. Riveted construction shall not be acceptable.

8-3.3*

Ducts shall be constructed of welded steel or other noncombustible material of equivalent strength. Ducts shall be properly supported and shall be protected against corrosion.

8-3.4*

Interior ducts shall be sufficiently strong to withstand maximum explosion pressures unless protected by a listed explosion suppression system (*see Chapter 3*). Exterior ducts shall be provided with explosion venting.

8-3.5*

Cyclone collectors, if used, shall be designed and constructed entirely of noncombustible material of adequate strength and rigidity to meet conditions of both service and installation requirements. Cyclone collectors or bag filters shall be protected by explosion vents.

Exception: A listed explosion suppression system designed in accordance with NFPA 69, Standard on Explosion Prevention Systems, is an acceptable alternative to explosion venting.

8-3.6*

Wood dust collectors that discharge into storage bins or silos shall do so in a manner that will minimize the generation of dust clouds. The discharge arrangement shall be constructed to minimize dust leaks and shall contain a choke to prevent explosion propagation between the collecting equipment and the storage facilities. Bins or silos shall be provided with explosion relief where practical (*see Chapter 3*).

8-3.7*

Sander systems shall be protected by explosion venting or a listed explosion suppression system (*see Chapter 3*).

8-4 Recycling Exhaust Air.

Filtered air shall not be recycled back into the building unless one of the following arrangements 8-4.1 or 8-4.2) is provided:

8-4.1

The system shall be equipped with a listed spark detection and suppression system. The recycled air duct shall be fitted with an abort damper that would be activated by the spark detector by passing the air to atmosphere, away from the plant. The abort damper shall be provided with a manual reset, so that, after it has aborted, it can only be returned to the closed position at the damper. Automatic or remote reset shall not be allowed.

8-4.2

The system shall be equipped with a listed spark detection and suppression system. The recycled air duct shall be provided with either an automatic fast-acting valve system or flame front diverter installed in accordance with NFPA 69, *Standard on Explosion Prevention Systems.*

8-5 Wood Scrap Disposal.

8-5.1

If the scrap wood is to be processed by hogs delivering small chips and shredded product for use as fuel or for other purposes, the discharge from such processing shall be handled as required in Sections 8-2 and 8-3.

8-5.2

If the scrap wood is to be processed by mills delivering a pulverized product, the requirements of Chapter 9 shall be complied with.

8-5.3

If the finely divided wood dust is to be used as a fuel, the applicable sections of NFPA 8503, *Standard for Pulverized Fuel Systems*, shall be adhered to.

8-5.4

Where wood waste is disposed of in an incinerator, it shall be in accordance with the requirements of NFPA 82, *Standard on Incinerators, Waste, and Linen Handling Systems and Equipment*.

Chapter 9 Thermal Oil Heating Systems

9-1* Scope.

This chapter shall apply to facilities that use heat transfer fluids to provide process equipment heat via piped, indirect heating systems.

9-2 General Provisions.

The applicable portions of NFPA 30, *Flammable and Combustible Liquids Code*, shall apply to thermal oil systems and plant areas having thermal oil piping or utilization equipment.

9-3* Thermal Oil Heaters.

9-3.1 Location and Construction.

9-3.1.1 Thermal oil heater rooms or buildings shall be protected by automatic sprinklers designed to control a hot oil-spill fire.

9-3.1.2 Thermal oil heaters shall be located and arranged to minimize the hazard from a potential oil spill.

9-3.1.3 The preferred location shall be outdoors or in a separate, detached building.

9-3.1.4 Where a detached location is not practical, the heater shall be located next to an outside wall and cut off from adjacent plant areas by a fire partition having at least a two-hour fire resistance. Also, the room shall be designed to contain the largest possible oil spill using curbs, dikes, sumps, floor drains, or other suitable means.

9-3.2 Oil Leak Detection.

9-3.2.1* A means shall be provided to automatically detect a tube leak inside the oil heat exchanger and minimize damage from an ensuing oil fire.

9-3.2.2* A means shall be provided to automatically detect major oil leaks in the utilization piping and equipment, and stop the flow of oil to the equipment.

9-3.3 Fuel Burner Controls and Interlocks.

9-3.3.1 Oil- or gas-fired burners shall be designed and installed in accordance with the applicable requirements of NFPA 8501, *Standard for Single Burner Boiler Operation*.

9-3.3.2 Wood dust suspension burners shall be designed and installed in accordance with the applicable requirements of NFPA 8503, *Standard for Pulverized Fuel Systems*.

9-3.3.3* Heaters that burn wood waste in a fluidized bed or on a grate shall provide a means to prevent the accumulation of explosive concentrations of combustibles in the heater, or any stack gas utilization equipment, following a shutdown with unburned fuel in the heater.

9-3.3.4 System heaters shall be under automatic control.

9-3.3.5 The heater shall automatically shut off on low liquid level, high liquid temperature, and low circulation rate.

9-3.3.6 Where oil heater stack gas is used to heat other utilization equipment, proper purging of the heater and utilization equipment shall be accomplished by the use of isolation gates, dampers, or suitable burner control logic. The control logic shall anticipate all operating modes of the oil heater and utilization equipment, either singly or together, to ensure safe start-up, shutdown, and upset conditions.

9-4 Thermal Oil Piping — Location and Construction.

9-4.1

Piping shall be routed outside or underground where practical.

9-4.2*

Where piping must be routed indoors, spill containment features, such as curbs, dikes, floor slope, drains, etc., shall be incorporated where practical.

9-4.3

Piping that is insulated shall use closed-cell, nonabsorptive insulation. Fibrous or open-cell insulation shall not be permitted.

9-4.4*

Piping shall be securely supported and otherwise protected against mechanical damage with adequate clearance from combustible material.

9-5 Thermal Oil Utilization Equipment.

9-5.1*

Where fire extinguishing systems are provided for utilization equipment, the system shall be designed to protect the equipment from a hot oil-spill fire or from the material being processed, whichever poses the more severe fire hazard.

Chapter 10 Wood Pulverizing Operations

10-1 Scope.

This chapter shall apply to those facilities involved in the manufacturing of wood flour or the pulverizing of wood to a size smaller than 100 mesh.

10-2 Location and Construction.

10-2.1*

Pulverizing operations shall be separated from all other buildings to prevent fire or explosion propagation.

10-2.2

The pulverizing process area shall be considered a dust explosion hazard with respect to construction and the need for explosion venting (*see Chapters 2 and 3*).

10-3 Protection of Openings.

When material presenting a dust explosion hazard is delivered to or from the pulverizing operation, chokes, rotary valves, explosion suppression systems, or other approved means shall be provided to prevent flame propagation through the conveying system.

10-4 Material Handling and Process Equipment.

10-4.1*

All equipment shall be installed so that constant true alignment is maintained and so that hot bearings and friction are avoided.

10-4.2*

Ball or roller bearings shall be used wherever practical. All bearings shall be dusttight.

10-4.3

Magnetic separators of the permanent magnet or self-cleaning electromagnet-type or pneumatic separators shall be installed ahead of mills and pulverizers.

10-5 Dust Control.

All dust-producing equipment shall be dusttight or the equipment and dust-producing operations shall be provided with dusttight hoods or enclosures that comply with the requirements of Section 8-3.

Chapter 11 Composite Board Plants

11-1 Scope.

This chapter covers the storage, preparation, and forming of wood particles or fibers into board form, including dry process hardboard, particleboard, medium density fiberboard, and oriented-strand board.

11-2 Location and Construction.

The following facilities shall be located outdoors or in separate buildings detached from the rest of the plant. These facilities shall be considered dust explosion hazards with respect to the need for explosion venting (*see 2-2.2 and Chapter 3*).

(a) Raw Material Storage

Exception: Storage that does not contain hazardous quantities of combustible dust or where the moisture content of the material stored is greater than 20 percent.

(b) Size Reduction Facilities

Exception: Where moisture content of the material being pulverized is greater than 20 percent, or where effective dust control measures prevent generation and accumulation of static or airborne dust in hazardous quantities.

(c) Particle Drying Facilities.

Exception: Where effective dust control measures prevent generation and accumulation of static or airborne dust in hazardous quantities.

11-3 Process Equipment.

11-3.1

Size reduction and particle-handling equipment shall meet the requirements of Sections 10-3 and 10-4, and 10-5.1.

11-3.2

Where conveying equipment passes between buildings or rooms that are designed to be isolated from each other, a conveyor choke or other approved means shall be provided to prevent explosion propagation.

11-3.3*

Dryers and board humidifiers shall be arranged and protected in accordance with the applicable requirements of NFPA 86, *Standard for Ovens and Furnaces*. The following requirements shall also apply to dryers:

11-3.3.1 Conveying equipment shall have facilities to divert burning material from the equipment downstream from the dryer to a safe dump area in the event of a fire in the dryer.

11-3.3.2* Thermal fire detectors shall be provided downstream from the dryers, normally in the ductwork at the dryer exit. The detection system shall be arranged to accommodate normal temperature surges associated with firing up of the unloaded dryer. Detectors shall activate the fire suppression systems, if provided, sound an alarm, shut off the fuel supply, divert burning material, and shut down preparatory process equipment.

11-3.3.3 Dryer systems having a dust explosion potential shall be protected by explosion venting or an approved explosion suppression system, unless the equipment can withstand the maximum expected explosion pressures (*see Chapter 3*). Dryer exhaust systems shall be designed in accordance with *Chapter 8*.

11-3.3.4* Diesel-powered front-end loaders used to handle or reclaim raw material inside storage buildings shall comply with the requirements for DS classification as described in NFPA 505, *Fire Safety Standard for Powered Industrial Trucks Including Type Designations, Areas of Use, Maintenance, and Operation*.

Exception: If the storage building complies with 11-2(a), a nonclassified front-end loader shall be permitted to be used.

Chapter 12 Referenced Publications

12-1

The following documents or portions thereof are referenced within this document and shall be considered part of the requirements of this document. The edition indicated for each reference is the current edition as of the date of the NFPA issuance of this document.

12-1.1 NFPA Publications.

National Fire Protection Association, 1 Batterymarch Park, P.O. 9101, Quincy, MA 02269-9101.

NFPA 10, *Standard for Portable Fire Extinguishers*, 1990 edition.

NFPA 11, *Standard for Low Expansion Foam and Combined Agent Systems*, 1988 edition.

NFPA 11A, *Standard for Medium- and High-Expansion Foam Systems*, 1988 edition.

NFPA 12, *Standard on Carbon Dioxide Extinguishing Systems*, 1993 edition.

NFPA 12A, *Standard on Halon 1301 Fire Extinguishing Systems*, 1992 edition.

NFPA 12B, *Standard on Halon 1211 Fire Extinguishing Systems*, 1990 edition.

NFPA 13, *Standard for the Installation of Sprinkler Systems*, 1991 edition.

NFPA 14, *Standard for the Installation of Standpipe and Hose Systems*, 1993 edition.

NFPA 15, *Standard for Water Spray Fixed Systems for Fire Protection*, 1990 edition

NFPA 17, *Standard for Dry Chemical Extinguishing Systems*, 1990 edition.

NFPA 24, *Standard for the Installation of Private Fire Service Mains and Their Appurtenances*, 1992 edition.

NFPA 30, *Flammable and Combustible Liquids Code*, 1993 edition.

NFPA 51B, *Standard for Fire Prevention in Use of Cutting and Welding Processes*, 1989 edition.

NFPA 69, *Standard on Explosion Prevention Systems*, 1992 edition.

NFPA 70, *National Electrical Code*, 1993 edition.

NFPA 80, *Standard for Fire Doors and Fire Windows,* 1992 edition.

NFPA 82, *Standard on Incinerators, Waste, and Linen Handling Systems and Equipment,* 1990 edition.

NFPA 86, *Standard for Ovens and Furnaces*, 1990 edition.

NFPA 91, *Standard for Exhaust Systems for Air Conveying of Materials*, 1992 edition.

NFPA *101*, *Life Safety Code*, 1991 edition.

NFPA 505, *Fire Safety Standard for Powered Industrial Trucks Including Type Designations, Areas of Use, Maintenance, and Operation*, 1992 edition.

NFPA 780, *Lightning Protection Code*, 1992 edition.

NFPA 8501, *Standard for Single Burner Boiler Operation*, 1992 edition.

NFPA 8503, *Standard for Pulverized Fuel Systems*, 1992 edition.

Appendix A Explanatory Material

This Appendix is not a part of the requirements of this NFPA document, but is included for information purposes only.

A-1-1.1

Such facilities include, but are not limited to, wood flour plants, woodworking plants, lumber mills, composite board plants, and large pattern shops in foundries.

A-1-1.2

Incidental operations are those typically limited to 6 to 8 people. Small-scale operations would not have more than 1 or 2 small dust collectors.

A-1-3

It is recommended that, wherever feasible, existing installations be modified to comply with the requirements of this standard.

A-1-4 Approved.

The National Fire Protection Association does not approve, inspect or certify any installations, procedures, equipment, or materials nor does it approve or evaluate testing laboratories. In determining the acceptability of installations or procedures, equipment or materials, the authority having jurisdiction may base acceptance on compliance with NFPA or other appropriate standards. In the absence of such standards, said authority may require evidence of proper installation, procedure or use. The authority having jurisdiction may also refer to the listings or labeling practices of an organization concerned with product evaluations which is in a position to determine compliance with appropriate standards for the current production of listed items.

A-1-4 Authority Having Jurisdiction.

The phrase “authority having jurisdiction” is used in NFPA documents in a broad manner since jurisdictions and “approval” agencies vary as do their responsibilities. Where public safety is primary, the “authority having jurisdiction” may be a federal, state, local or other regional department or individual such as a fire chief, fire marshal, chief of a fire prevention bureau, labor department, health department, building official, electrical inspector, or others having statutory authority. For insurance purposes, an insurance inspection department, rating bureau, or other insurance company representative may be the “authority having jurisdiction.” In many circumstances the property owner or his designated agent assumes the role of the “authority having jurisdiction”; at government installations, the commanding officer or departmental official may be the “authority having jurisdiction.”

A-1-4 Listed.

The means for identifying listed equipment may vary for each organization concerned with product evaluation, some of which do not recognize equipment as listed unless it is also labeled. The “authority having jurisdiction” should utilize the system employed by the listing organization to identify a listed product.

A-2-1.1

All buildings should be of Type I or Type II construction, as defined in NFPA 220, *Standard on Types of Building Construction*.

A-2-1.2

All conveyor, chute, and pipe openings through floors should be tight or should be protected by approved automatic closing fire doors or fire dampers having a fire endurance rating equal to the floor being penetrated.

Buildings using open space separation techniques should refer to NFPA 80A, *Recommended Practice for Protection of Buildings from Exterior Fire Exposures*.

A-2-2.3

See NFPA 68, *Guide for Venting of Deflagrations*, for guidance on the strength of relieving and resisting walls.

A-2-3.4

Such doors should be marked “Not An Exit.” The unique requirements of doors in explosion-resistant walls preclude their use as a means of egress because NFPA *101*, *Life Safety Code*, requires exit doors from high hazard areas to swing in the direction of exit travel.

A-2-5.2

As much as a 60-degree angle of inclination might be necessary for maximum effectiveness with many types of wood dust.

A-3-1

In general, dust particles need to be below 420 μm (microns) (U.S. sieve No. 40) to create a dust explosion hazard. The degree of explosion hazard will vary depending on the type of combustible dust and processing methods used. A dust explosion has three requirements, all of which must be met:

(a) The dust must be combustible

(b) The dust particles must form a cloud at or exceeding the minimum explosion concentration

(c) A source of ignition must be present.

A-3-1.1

Refer to NFPA 68, *Guide for Venting of Deflagrations*, for sizing of explosion vents.

A-3-1.2

See "Explosion Venting as a Means of Controlling Dust Explosions," Frank, T.E., and "Explosion Venting of Industrial Air Systems," Pauli, L.E., Proceedings of the 12th Annual Particleboard Symposium, Washington State University, Pullman, WA, 1978.

A-4-1.3

Unapproved vacuum cleaning equipment can be used if the powered suction source is located in a remote, nondusty area.

A-4-1.4

It is recommended that cleaning by this method be done when the portion of the plant being cleaned is not operating. Electrical equipment suitable for Class II locations need not be de-energized during blowdown.

A-4-3

Consideration should be given to the use of fire-resistant hydraulic fluids to reduce the fire hazards of hydraulic systems in plant process equipment.

A-5-1.2

Refer to NFPA 497B, *Recommended Practice for the Classification of Class II Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas*.

A-6-2.1

Grounding and bonding information can be found in NFPA 77, *Recommended Practice on Static Electricity*.

A-7-1.2

Inside $1^1/_2$-in. (3.8-cm) hose stations are recommended throughout all major woodworking facilities. Directional water spray nozzles or combination straight stream/water spray nozzles are recommended since careless use of straight hose streams can cause dust explosions by throwing hazardous quantities of dust into suspension.

A-7-2

Automatic sprinkler protection is recommended throughout all major woodworking facilities.

Press pits, press hoods, and hood ventilating fans should be protected by automatic sprinkler systems, deluge systems, or both. It is important that sprinkler and deluge heads be located so that hard-to-reach places, such as spaces between press cylinders, are properly protected.

A-8-2.1

Each system should consist of branch ducts connected to hoods or enclosures, one or more main ducts, airflow-producing equipment, a discharge duct to the out-of-doors, and a means for separating the entrained wood particles from the air flowing in the system.

A-8-2.2

Although the exceptions allow dust collectors indoors under certain conditions, the preferred location is outdoors.

A-8-2.2 Exception No. 1.

See NFPA 68, *Guide for Venting of Deflagrations*, for designing explosion venting.

A-8-3.1

Air conveying systems, such as from a hog or hammermill, can fall within the scope of this section depending on the moisture content and particle size of the dust generated.

A-8-3.3

Ducts with circular cross section are preferable to square or rectangular ducts. Welded steel of 12-gauge minimum thickness is normally strong enough to prevent failure during an explosion. This is especially true for small ducts. However, for large rectangular ducts, 12 gauge might not be adequate.

A-8-3.4

An approved spark detection and extinguishing system should be considered to quench burning material before it can be conveyed into the collecting equipment.

Also, when bag filters are used with the conveying air-flow fan located ahead of the bag filters, a high-speed abort gate activated by infrared spark detectors should be used to divert burning material before it can enter the bag filter. (*See Appendix B, Frank, T. E., "Fire and Explosion Control in Bag Filter Dust Collection Systems," NFPA Fire Journal, Vol. 75, No. 2, March 1981, p. 73.*)

It is advisable for outdoor ducts to be provided with explosion venting to help minimize the overall pressure buildup resulting from a deflagration. For information on explosion venting, see NFPA 68, *Guide for Venting of Deflagrations*.

A-8-3.5

Collecting equipment should be protected by automatic sprinklers or an approved water spray system (*see Chapter 7*). Where bag filters are used, consideration should be given to their use as primary collectors, eliminating the cyclone. Collectors and filters should be located outside the building, on independent supporting structures, and should be accessible for fire fighting. It is not advisable to locate collectors and filters on the roofs of buildings. Welded steel of 12-gauge minimum thickness is normally of sufficient strength to prevent structural failure during an explosion, if adequate explosion venting or suppression is provided.

A-8-3.6

Storage bins and silos should be protected by automatic sprinklers or an approved water spray system (*see Chapter 7*). Storage bins and silos should be located outside the building on independent supporting structures and should be accessible for fire fighting. It is not advisable to locate bins or silos on the roofs of buildings.

A-8-3.7

An infrared spark detection system should be considered to shut down the sander, stop material infeed, initiate a water spray deluge in the collecting system, and activate a fire dump in the collecting system outfeed. The exhaust system main fan should be left running to purge the system of dust and to help keep dust from dropping into suspension from dust filters.

A-9-1

Thermal oil heating systems have been used to heat lumber dry kilns, plywood veneer dryers, plywood and composite board presses, composite board furnish dryers, and also for building heat.

A-9-3

A thermal oil heating system typically consists of a central heat exchanger to heat the thermal fluid. Firing can be by conventional gas or oil burners, wood dust suspension burners, or special wood waste combustors, such as fluidized bed burners or “wet cell” burners, which partially burn and gasify wood waste on a grate using sub-stoichiometric under-fire airflow, and complete the combustion in an upper plenum using secondary air injection. The hot gases then pass through a heat exchanger to indirectly heat the thermal fluid. The heat exchanger may be a separate, stand-alone unit, or an integral part of the heater. Conventional water-tube boilers have even been used as heaters, with thermal fluid replacing the water.

The thermal fluids used are typically special oils developed for this type of application, with flash points of several hundred degrees Fahrenheit. For maximum thermal efficiency, they are usually heated above their flash points, making an oil spill especially hazardous. Also, because of the high oil temperatures, it is usually necessary to keep the oil circulating through the heat exchanger at all times to prevent oil breakdown and tube fouling. Diesel-driven pumps or emergency generators are usually provided for this purpose in case of a power outage. Oil circulation can even be needed for a period of time after burner shutdown due to the latent heat in the heater.

A-9-3.2.1 A tube rupture during heater operation would likely result in an instantaneous fire. A small leak could result in a localized oil spray fire, which could cause tube fouling from oil breakdown or tube rupture from overheating. A major leak would result in extensive damage and downtime since it is not practical to shut off the oil pumps (*see A-9-3*).

Loss of oil in the system can be detected by monitoring the oil level in the expansion tank. This in itself would not indicate a leak inside the heater. Additional flue gas instrumentation such as high temperature, combustibles, or opacity can be used to indicate a leak within the heater. These signals could then be combined to activate automatic emergency interlocks [*see Figure A-9-5.1(a)*].

Inert gas extinguishing systems (carbon dioxide, nitrogen, or steam) can be used to control fires in heaters. The feasibility of this method depends on the size and configuration of the heater. With this method, it is necessary to maintain an extinguishing concentration of inert gas inside the heater for a period of time long enough to allow hot refractory and other heater components to cool, or else re-ignition can occur.

A novel approach to minimizing fire damage is to rapidly drain all the oil from the heater. An oil drain tank is generally provided with the heater for maintenance, and it can be used, with suitable modifications, for emergency drain purposes.

Refer to Figures A-9-5.1(a) and A-9-5.1(b) for simple logic and schematic diagrams of typical protection schemes.

A-9-3.2.2 Hot oil from tube leaks outside the heater can create hazardous spills. Small leaks are of less concern and would likely be detected by personnel before a large spill occurred. A low-level alarm in the heater expansion tank should be used to detect gradual loss of oil in the system. Large spills or pipe breaks are of greater concern. Most systems utilize low-oil-pressure interlocks to start emergency oil circulation pumps. Momentary low oil pressure would be expected from a major pipe rupture. This signal, coupled with a low expansion tank level, can be used to distinguish a major pipe rupture from some other nonhazardous low-pressure condition.

To stop the flow of oil to the utilization equipment, an alternate path must be available to keep oil flowing through the heater. If no other utilization loops are provided, an emergency loop should be provided for this purpose. It may be necessary to have a dummy cooling load so as not to overheat the oil.

Refer to Figures A-9-5.1(a) and A-9-5.1(b) for simple logic and schematic diagrams of typical protection schemes.

A-9-3.3.3 Fluidized bed burners and burners that combust wood waste on a grate contain a quantity of unburned fuel during normal operation. They cannot be instantly shut off like a conventional gas, oil, or pulverized fuel suspension burner. During any emergency stop or other shutdown that does not fully combust the bed of fuel, combustibles (mostly carbon monoxide with small amounts of hydrogen) will be generated due to the latent heat in the fire box and lack of enough air for complete combustion.

Heaters that exhaust directly into a stack can usually prevent the accumulation of explosive concentrations of combustibles by natural draft means. Some facilities recover additional heat from the thermal oil heater stack gas by ducting the burner exhaust into other utilization equipment. Natural draft is unreliable in these instances, and other means, such as automatic-opening emergency vents on the burner exhaust duct, isolation dampers, or inert gas padding systems, should be used to prevent buildup of explosive concentrations of combustibles.

A-9-4.2

Concentric piping can materially lessen the spill potential as long as the annular space is monitored to detect leakage.

A-9-4.4

Proper clearance from combustibles should be determined based on the operating surface temperature of the insulated pipe. Piping should be kept free of combustible dust accumulations.

A-9-5.1

The fire hazard in process equipment such as veneer dryers, lumber dry kilns, composite panels press pits, etc., will likely be more severe than normal from a hot oil-spill fire. When this is the case, automatic sprinkler or deluge protection should be provided for the process equipment, with the system designed for the more severe hazard.

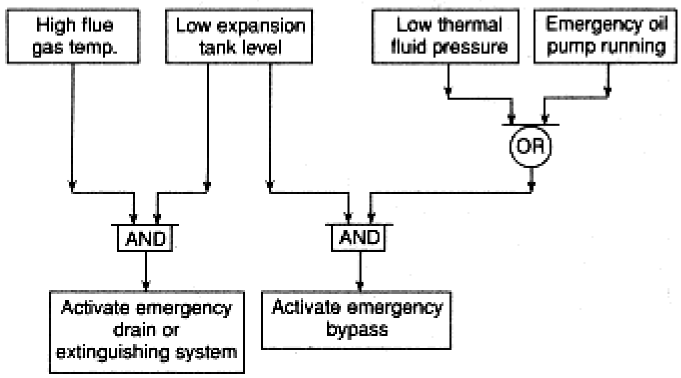


Figure A-9-5.1(a) Typical oil leak detection logic.

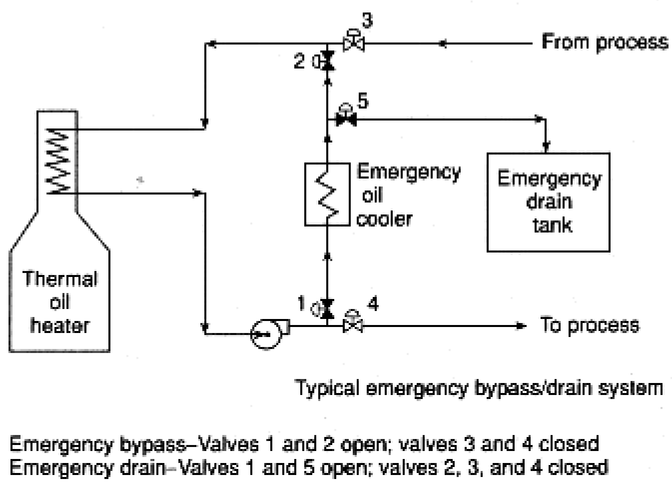


Figure A-9-5.1(b) Thermal oil heating system major leak detection/protection.

A-10-2.1

Separation can be accomplished by a physical distance of 50 ft (15 m) or by properly designed pressure-resistant barriers with directional venting.

A-10-4.1

Equipment should be installed and arranged in unit systems so that each pulverizer will deliver to a single set of scalpers and bolters. Interconnections between sets of equipment should not be permitted unless the material passing from one unit to another is conveyed through conveyors containing positive chokes.

A-10-4.2

Bearings in dusty or inaccessible locations where overheating of bearings can result in fires or explosions should be provided with approved journal alarms.

A-11-3.3

The preferable fire protection system for a hardboard humidifier, board bake oven, or tempering oven is an automatic water spray system with manual override.

A-11-3.3.2 An infrared spark detection system located downstream from the dryer should be considered, in addition to the thermal fire detection system.

A-11-3.3.4 To further reduce the hazard, fixed automatic dry chemical extinguishing systems should be provided on these vehicles.

Appendix B Referenced Publications

B-1

The following documents or portions thereof are referenced within this document for informational purposes only and thus are not considered part of the requirements of this document. The edition indicated for each reference is the current edition as of the date of the NFPA issuance of this document.

B-1.1 NFPA Publications.

National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.

NFPA 68, *Guide for Venting of Deflagrations*, 1988 edition.

NFPA 77, *Recommended Practice on Static Electricity*, 1993 edition.

NFPA 80A, *Recommended Practice for Protection of Buildings from Exterior Fire Exposures*, 1993 edition.

NFPA *101*, *Life Safety Code*, 1991 edition.

NFPA 220, *Standard on Types of Building Construction*, 1992 edition.

NFPA 497B, *Recommended Practice for the Classification of Class II Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas*, 1991 edition.

B-1.2 Other Publications.

Frank, T. E., “Fire and Explosion Control in Bag Filter Dust Collection Systems,” *NFPA Fire Journal*, Vol. 75, No. 2, March 1981, p. 73.

Frank, T. E., “Explosion Venting as a Means of Controlling Dust Explosions,” *Proceedings* of the 12th Annual Particleboard Symposium, 1978.

Pauli, L. E. “Explosion Venting of Industrial Air Systems,” *Proceedings* of the 12th Annual Particleboard Symposium, 1978.

Formal Interpretation

NFPA 664

Wood Processing and Woodworking Facilities

1993 Edition

Reference : 8-4, 8-4.1, and 8-4.2
F.I. 87-1

Question 1: Would the intent of 8-4 be met with the installation of single spark detectors which control both the suppression system and the abort dampers?

Answer: Yes.

Question 2: Is it the intent of 8-4.1 to require an approved spark detection and suppression system be installed on the inlet side of the recirculating type dust collector?

Answer: Yes.

Question 3: Is it the intent of 8-4.2 to require a separate spark detector on the recycled air duct to activate the abort damper?

Answer: No.

Issue Edition: 1987
Reference: 8-4, 8-4.1(a), and 8-4.1(b)
Issue Date: December 3, 1992
Effective Date: December 23, 1992

NFPA 701

1996 Edition

Standard Methods of Fire Tests for Flame-Resistant Textiles and Films

1996 Edition

This edition of NFPA 701, *Standard Methods of Fire Tests for Flame-Resistant Textiles and Films*, was prepared by the Technical Committee on Fire Tests and acted on by the National Fire Protection Association, Inc., at its Fall Meeting held November 13-15, 1995, in Chicago, IL. It was issued by the Standards Council on January 12, 1996, with an effective date of February 2, 1996, and supersedes all previous editions.

This edition of NFPA 701 was approved as an American National Standard on February 2, 1996.

Origin and Development of NFPA 701

Requirements for flameproofing of textiles were adopted by the NFPA on recommendation of the Committee on Fireproofing and Preservative Treatments in 1938. These requirements were amended in 1939, 1940, 1941, and 1951. This standard is now under the jurisdiction of the NFPA Technical Committee on Fire Tests; the 1966 edition, which was an extensive revision of the previous edition, was prepared by that committee, as were the 1968, 1969, 1975, 1976, and 1977 editions.

The 1989 edition was a complete rewrite with significant changes to the small-scale test.

The 1996 edition represents a significant departure from earlier editions, as it provides a new test for single-layer and multilayer fabric assemblies but maintains the large-scale test for multilayer assemblies involving coated fabric blackout linings. This new test was developed to address the problem presented by multilayer assemblies that could not be addressed by the current test procedures. The new Test 1 has been proven through experience to be an adequate predictor of the behavior of single-layer and multilayer assemblies.

Technical Committee on Fire Tests

Marc L. Janssens, American Forest & Paper Assn., DC

James R. Lawson, U.S. Nat'l Inst. of Standards and Technology, MD

Gerald E. Lingenfelter, American Insurance Services Group, Inc., NY

William S. Metes, Underwriters Laboratories Inc., IL

George E. Meyer, Warnock Hersey Int'l, Inc., CA

John W. Michener, Milliken Research Corp., SC
Rep. American Textile Mfrs. Inst. Inc.

James A. Milke, University of Maryland, MD

James C. Norris, Union Carbide, PA

Sivon C. Reznikoff, Arizona State University, AZ

John Roberts, Underwriters Laboratories of Canada, ON

Herman Stone, General Foam, PA

T. Hugh Talley, Hugh Talley Co., TN
Rep. Upholstered Furniture Action Council

Richard P. Thornberry, The Code Consortium, Inc., CA

Robert J. Wills, American Iron & Steel Inst., AL

Peter J. Gore Willse, Industrial Risk Insurers, CT
Rep. Industrial Risk Insurers

Alternates

Peter H. Billing, American Forest & Paper Assn., FL
(Alt. to M. L. Janssens)

Delbert F. Boring, American Iron & Steel Inst., OH
(Alt. to R. J. Wills)

Tony Crimi, Underwriters Laboratories of Canada, ON
(Alt. to J. Roberts)

Philip J. DiNenno, Hughes Assoc., Inc., MD
(Alt. to J. J. Beitel)

Richard D. Gottwald, Society of the Plastics Industry Inc., DC
(Alt. to J. A. Blair)

Arthur J. Parker, Southwest Research Inst., TX
(Vot. Alt. to SRI Rep.)

R. Joseph Pearson, Inchcape Testing Services, NY
(Alt. to G. E. Meyer)

William A. Thornberg, Industrial Risk Insurers, CT
(Alt. to P. J. G. Willse)

James J. Urban, Underwriters Laboratories Inc., IL
(Alt. to W. S. Metes)

Kay M. Villa, American Textile Mfrs. Inst. Inc., DC
(Alt. to J. W. Michener)

Joe Ziolkowski, American Furniture Mfrs. Assoc., NC
(Alt. to T. H. Talley)

Nonvoting

A. J. Bartosic, Rohm & Haas Co., PA

Tod L. Jilg, Hoechst Celanese, NC

Herman H. Spaeth, Novato, CA
(Member Emeritus)

Walter P. Sterling, NFPA Staff Liaison

This list represents the membership at the time the Committee was balloted on the text of this edition. Since that time, changes in the membership may have occurred.

NOTE: Membership on a Committee shall not in and of itself constitute an endorsement of the Association or any document developed by the Committee on which the member serves.

Committee Scope: This Committee shall have primary responsibility for documents on fire testing procedures when such standards are not available; for reviewing existing fire test standards and recommending appropriate action to NFPA; for recommending the application of and advising on the interpretation of acceptable test standards for fire problems of concern to NFPA technical committees and members; and for acting in a liaison capacity between NFPA and the committees of other organizations writing fire test standards. This committee does not cover fire tests that are used to evaluate extinguishing agents, devices, or systems.

NFPA 701

Standard Methods of Fire Tests for

Flame-Resistant Textiles and Films

1996 Edition

NOTICE: An asterisk (*) following the number or letter designating a paragraph indicates explanatory material on that paragraph in Appendix A.
Information on referenced publications can be found in Chapter 15 and Appendix E.

Chapter 1 Introduction

1-1 Purpose of Test 1 and Test 2.

1-1.1

It is the purpose of these test methods to assess the propagation of flame beyond the area exposed to the ignition source.

1-1.2

These test methods do not indicate whether the material tested resists the propagation of flame under more severe exposure conditions or where used in a manner that differs substantially from the test conditions.

1-1.3

Test 1 differentiates fabrics that do not spread flame extensively from those that do burn rapidly and extensively.

1-1.4

Test 1 provides a procedure for assessing the response of fabrics both individually and in multilayer composites used as curtains, draperies, or other window treatments when exposed to a moderate flame while suspended in a vertical configuration.

1-1.5

Test 2 provides a comparison among materials using a moderate size ignition flame.

1-1.6

Flame-resistant requirements shall not be dependent on the type of treatment; however, where durability to cleaning or weathering is claimed, the fabric or material shall be tested for flame resistance as produced and after being subjected to the applicable cleaning or exposure procedures. (*See Chapter 13.*)

1-1.7

Where materials are to be applied to surfaces of buildings or backing materials as interior finishes for use in buildings, the test shall be conducted and the material classified in accordance with NFPA 255, *Standard Method of Test of Surface Burning Characteristics of Building Materials*.

1-2 Scopes.

1-2.1 Test Method 1.

1-2.1.1 This test method shall apply to fabrics (except for vinyl-coated fabric blackout linings) or other materials used in curtains, draperies, or other window treatments.

1-2.1.2 This test method shall apply to single-layer fabrics and multilayer curtain and drapery assemblies (except for vinyl-coated fabric blackout linings) in which the layers are fastened together by sewing or other means for holding portions of the assembly in intimate contact.

1-2.1.3 For the purposes of this test method, where the terms curtains, draperies, or other window treatments are used, they also shall include, but shall not be limited to, the following items:

(a) Window curtains;

(b) Stage or theater curtains;

(c) Vertical folding shades;

(d) Roll-type window shades;

(e) Hospital privacy curtains;

(f) Window draperies;

(g) Fabric vertical shades or blinds;

(h) Horizontal folding shades;

(i) Swags;

(j) Fabric horizontal shades or blinds.

1-2.1.4 This test method also shall apply to the following textile items:

(a) Table skirts;

(b) Table linens;

(c) Display booth separators;

(d) Textile wall hangings.

1-2.1.5 This test method shall not apply to fabrics or composites greater than 700 g/m^2 (21 oz/yd^2).

1-2.2 Test Method 2.

1-2.2.1 This test method shall be used for testing coated fabric blackout linings and lined draperies using a coated fabric blackout lining.

1-2.2.2 This test method shall be used for testing plastic films, with or without reinforcement or backing, where used for decorative or other purposes inside a building or as temporary or permanent enclosures for buildings under construction.

1-2.2.3 This test method shall apply to fabrics used in the assembly of awnings, tents, tarps, and similar architectural fabric structures and banners.

1-2.2.4 This test method (flat specimen configuration) shall be used for fabrics and films, with or without reinforcing or backing, that weigh in excess of 700 g/m^2 (21 oz/yd^2).

Chapter 2 Test 1

2-1 General.

2-1.1

The specimens shall be suspended from a pin bar.

2-1.2

A weighed specimen consisting of one or more layers of fabric shall be suspended vertically from a pin bar near the top rear of an open-face test cabinet. A specified gas flame shall be applied to the center of the lower edge of the specimen for 45 seconds and then withdrawn. The specimen shall be allowed to burn until the flame self-extinguishes and there is no further specimen damage. The specimen then shall be removed from the pin bar and weighed again. The percent weight loss shall be determined and used as a measure of total flamespread and specimen damage.

2-2 Conditioning Oven.

A forced draft oven, capable of maintaining a temperature of 105°C ± 3°C (220°F ± 5°F), shall be used to condition the test specimens prior to testing.

2-3 Hood.

A standard laboratory hood [minimum 820 mm (32 in.) wide by 750 mm (30 in.) high by 630 mm (25 in.) deep] or other suitable enclosure shall be used and shall provide a draft-free environment around an open-face test chamber. The hood or other enclosure shall be equipped with an exhaust fan for exhausting the smoke as provided in 5-3.2.

2-4 Test Chamber, Specimen-Mounting Pin Bar, and Gas Burner.

2-4.1

An open-face test chamber is shown in Figure 2-4.1(a). The test chamber shall be constructed in accordance with Figure 2-4.1(a) using 12-mm (0.5-in.) thick marinite mineral board. All interior surfaces of the cabinet shall be painted with a flat black paint that withstands the heating that occurs in the cabinet. Figure 2-4.1(b) shows a sketch of the cabinet with the burner and specimen in place.

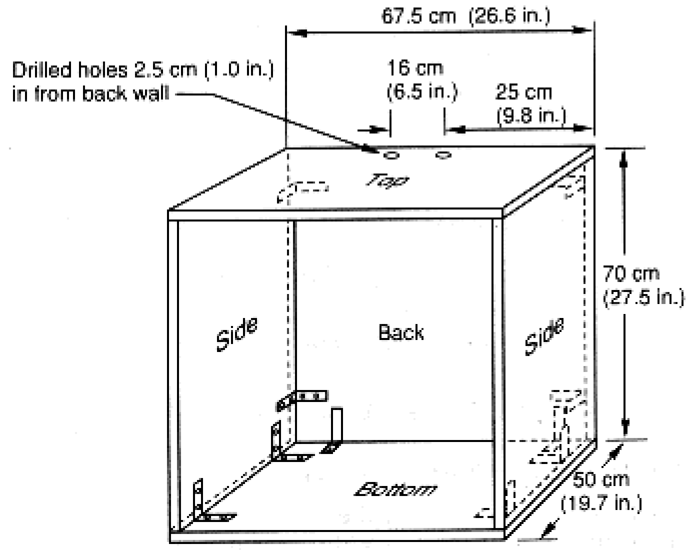


Figure 2-4.1(a) Test cabinet for Test 1.

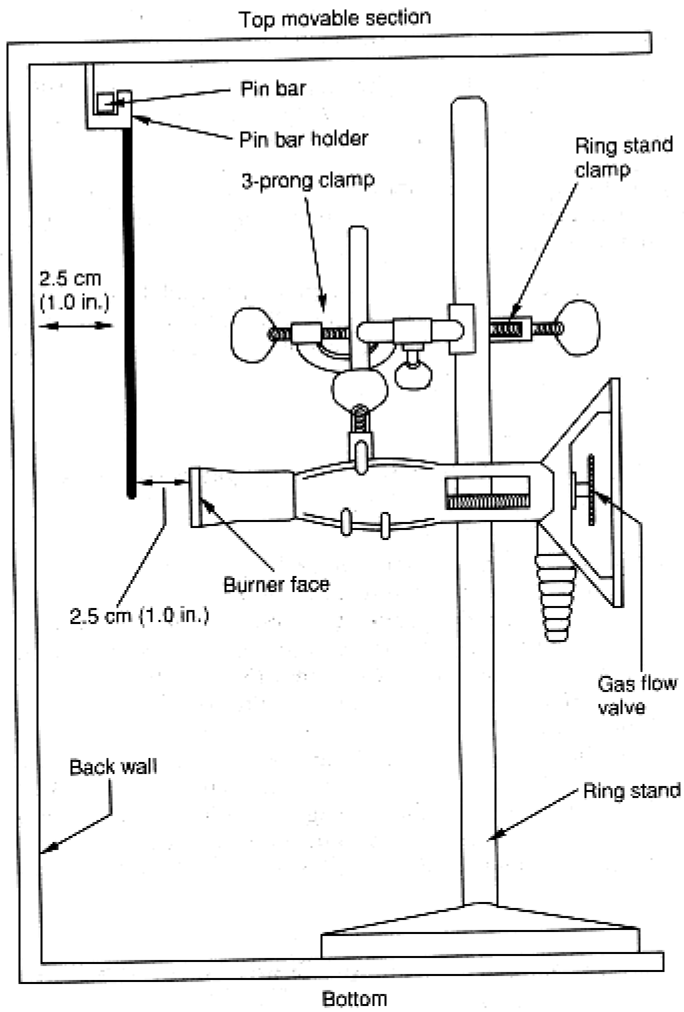


Figure 2-4.1(b) Schematic of burner and specimen placement for Test 1.

2-4.2*

The pin bar for mounting the specimen shall be a 9-mm^2 (0.36-in.^{2}) stainless steel bar, 190 mm (7.5 in.) in length, with steel pins 0.7 mm (0.027 in.) in diameter and 11 mm (0.43 in.) long, mounted at distances of 37 mm, 66 mm, 95 mm, 124 mm, and 153 mm (1.45 in., 2.60 in., 3.75 in., 4.90 in., and 6.05 in.) from each end of the bar. (*See Appendix A for information on a suitable alternate test cabinet*.)

2-4.3*

A Meeker (Fisher) burner shall be used as the ignition source.

2-5 Gas and Control System.

2-5.1*

Methane gas that is at least 97 percent pure shall be used for the burner fuel. The gas shall be contained in a cylinder equipped with a pressure-reducing valve and gauges to allow maintenance of a pressure of 17.5 kPa ± 2.0 kPa (2.5 psi ± 0.25 psi) (132 mm Hg ± 13 mm Hg) at the flow gauge.

2-5.2*

A gas flow gauge with a flow control valve shall be used to measure and control the gas flow rate.

2-5.3

The gas tank, flow gauge, control valves, and burner shall be connected as shown in Figure 2-5.3. Hose or tubing with at least a 5-mm (0.2-in.) bore shall be used. The control valve at the tank shall not be used to control the flow through the flow gauge. The flow valve at the tank shall be fully open during the test.

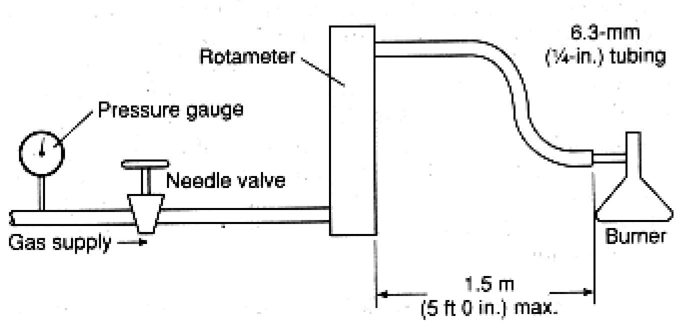


Figure 2-5.3 Gas line feed arrangement to burner.

2-6 Mounting Jig.

A mounting jig, as described in Appendix B, shall be used for mounting specimens to the pin bar in a uniform and safe manner.

2-7 Timer.

A stopwatch or other timing device shall be used to measure time to the nearest 0.2 second.

2-8 Balance.

A balance having a capacity of at least 100 g (3.53 oz) and a resolution of 0.1 g (3.5×10^{-3} oz) shall be used to weigh the specimen.

2-9 Ruler.

A ruler, marked in 1-mm ($^{1}/_{32}$-in.) increments, shall be used to measure the burner flame height and specimen dimensions.

2-10* Wire Brush.

A brush manufactured from bronze wire shall be used for removing ash and char debris from the test specimen at the conclusion of each test and before the post-test weighing.

Chapter 3 Calibration and Standardization for Test 1

3-1 General.

At the start of each series of tests, the air vents at the base of the burner shall be fully open and the gas flow set for a flow gauge scale reading of 70 ± 2 using the flow control valve on the gauge. This corresponds to an airflow of 895 ml/min ± 25 ml/min (5.26×10^{-10} ft^3/sec ± 1.47×10^{-15} ft^3/sec) and a methane flow of 1205 ml/min ± 35 ml/min (7.1×10^{-4} ft^3/sec ± 2.0×10^{-5} ft^3/sec). At the same time, the pressure gauge shall read 17.5 kPa ± 2.0 kPa (2.5 psi ± 0.25 psi) (132 mm Hg ± 13 mm Hg). This shall provide a flame height of 100 mm ± 10 mm (4.0 in. ± 0.4 in.) with the burner in a vertical position. The flow control valve on the burner shall be fully open.

Chapter 4 Specimens and Conditioning for Test 1

4-1 Test Specimens.

4-1.1

Ten individual test specimens shall be cut from a single piece of the material to be evaluated to a size of 150 mm ± 5 mm × 400 mm ± 5 mm (5.90 in. ± 0.20 in. × 15.75 in. ± 0.20 in.), with the length parallel to the lengthwise direction of the material. These 10 specimens constitute a sample. Specimens shall not be taken nearer the selvage than $^{1}/_{10}$ of the full width of the fabric.

4-1.2

For multilayer assemblies, the layers shall be sewn together as shown in Figure 4-1.2 using a plain stitch with 2.5 stitches/cm ± 0.25 stitch/cm (6.4 stitches/in. ±0.6 stitch/in.). A No. 40 polyester/cotton sewing thread shall be used. The layers of the multilayer assembly shall be sewn along all four edges at a distance of 5 mm ± 1 mm (0.2 in. ± 0.04 in.) from the edge. A fifth seam shall be sewn along the center of the assembly in the lengthwise direction. This center seam shall extend the full length of the specimen.

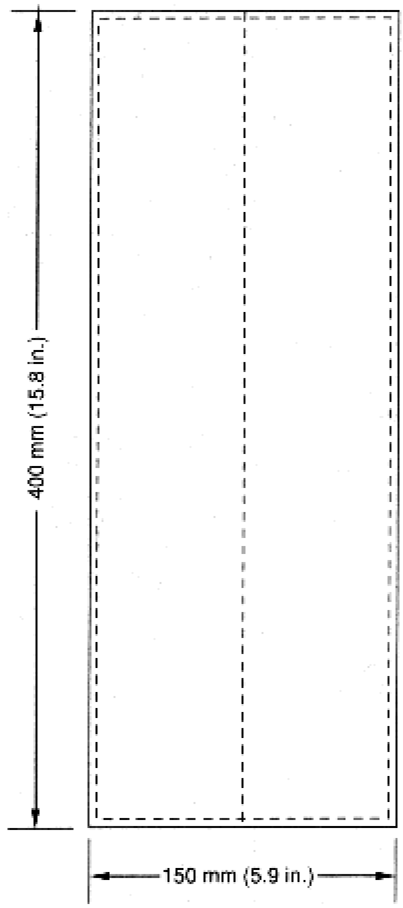


Figure 4-1.2 Multilayer specimen for Test 1.

4-1.3

Each specimen shall be numbered and weighed to the nearest 0.1 g (3.5 × 10^{-3} oz) before conditioning. The weight of each specimen shall be recorded.

4-2 Conditioning.

The specimens shall be placed in a forced draft oven to allow free circulation of air around the specimens. The specimens shall be dried for at least 30 minutes at 105°C ± 3°C (220°F ± 5°F).

Chapter 5 Test Procedure for Test 1

5-1 Mounting of Test Specimens.

5-1.1

After conditioning, the specimen shall be attached to the pin bar with the top of the specimen centered on the bar. The pins shall be 5 mm ± 1 mm (0.20 in. ± 0.04 in.) from the top edge of the specimen. The mounting jig described in Appendix B shall be used. The specimen shall be placed on the pin bar so that the face or the layer intended to face the wall or window during normal use faces the pin bar.

5-1.2

The pin bar shall be mounted on the support hanger located at the back of the ceiling of the test chamber. The face, which in normal use is intended to face the wall or window, shall face the back of the test chamber. When the pin bar and hanger are placed, the side of the specimen facing the back wall of the test chamber shall be 25 mm ± 2 mm (1.0 in. ± 0.08 in.) from the wall surface.

5-2 Burner Placement and Preparation.

5-2.1

The burner shall be placed so that it is 25 mm ± 2 mm (1.0 in. ± 0.08 in.) from the face of the specimen and with the center axis of the burner horizontal and in line with the bottom of the center seam in the specimen. Position adjustments shall be permitted to be made by moving the support base and by adjusting the height and angle of the burner.

5-2.2

The exhaust fan shall be turned on.

5-3 Conducting the Test.

5-3.1

The test shall be initiated within 2 minutes after removing the specimen from the forced draft oven. The gas shall be turned full on at the burner control valve. The gas shall be flowed for 20 sec ± 1 sec. The gas then shall be ignited. The flame shall burn for 45 sec ± 1 sec. After the 45-second exposure, the burner shall be turned on its mount so that its center axis is parallel to the plane of the specimen, and then the gas shall be turned off using the control valve on the burner. The gas flow rate shall be controlled only by the valve on the flow gauge. The valve on the burner shall be turned off completely and then turned on completely for the duration of the test exposure, and then it shall be closed completely at the end of the 45-second exposure time.

5-3.2

The exhaust fan shall remain on throughout the test procedure. The front of the hood shall be closed after the burner is turned off and pulled away from the specimen to remove the smoke produced by the burning specimen.

5-3.3

The afterflame time of the specimen (time of burning of the specimen after the gas flow is turned off) and the time of burning of material that falls to the bottom of the chamber shall be measured and recorded. Observations such as, but not limited to, the type, amount, color, density, and odor of smoke produced, the vigorousness of burning, and the dripping of molten material also shall be recorded.

5-3.4

The pin bar and specimen shall be removed from the hanger.

5-3.5

The wire brush shall be used to remove ash and char from the specimen.

5-3.6

The specimen shall be removed from the pin bar.

5-3.7

The portion of the specimen removed from the pin bar shall be weighed to the nearest 0.1 g (3.5×10^{-3}) and the weight shall be recorded. Any material that has fallen away from the specimen shall not be weighed.

Chapter 6 Calculation of Results for Test 1

6-1 Calculation of Percent Weight Loss.

6-1.1

The percent weight loss of each specimen shall be determined from the following equation:

$$\frac{\text{Weight before test} - \text{Weight after test}}{(\text{Weight before test})} \times 100 = \text{Percent weight loss}$$

The percent weight loss shall be recorded.

6-1.2

The mean percent weight loss and the standard deviation for the sample consisting of 10 specimens shall be calculated.

6-1.3

Where the percent weight loss of any individual specimen exceeds the mean value plus three standard deviations, the test shall be repeated on another sample of 10 specimens. The mean percent weight loss and standard deviation for the second set of 10 specimens shall be calculated.

Chapter 7 Flame Resistance Performance Criteria for Test 1

7-1 Performance Criteria.

7-1.1

Where fragments or residues of specimens that fall to the floor of the test chamber continue to burn for more than an average of 2 seconds per specimen for the sample of 10 specimens, the material shall be recorded as failing Test 1.

7-1.2

Where the average weight loss of the 10 specimens in a sample is greater than 40 percent, the material shall be recorded as failing this test.

7-1.3

Where the percent weight loss of any individual specimen in the second set of specimens exceeds the mean value of the second set plus three standard deviations calculated for the second set, the material shall be recorded as failing this test.

7-1.4

Where the specimens do not demonstrate performance in accordance with any of the conditions indicated in 7-1.1 through 7-1.3, the material shall be recorded as passing this test and shall be designated as flame resistant.

Chapter 8 General Requirements for Test 2

8-1 General.

8-1.1

This test method provides a comparison among materials using a moderate size igniting flame.

8-1.2

This large-scale test exposes a 1.2-m (47.25-in.) long specimen to a 280-mm ± 12 mm (11.0-in. ± 0.5 in.) igniting flame inside a three-sided test cabinet that is 305 mm^2 (12 $in.^2$) and 2.13 m (84 in.) high.

Chapter 9 Test Apparatus and Materials for Test 2

9-1 Conditioning Oven.

9-1.1

A forced draft oven shall be used to condition test specimens prior to testing.

9-1.1.1 The interior of the oven shall provide free airflow around each specimen it contains.

9-1.1.2 An oven having variable temperature control capable of maintaining its interior at a temperature of 105°C ± 3°C (220°F ± 5°F) shall be used.

9-2 Test Enclosure.

9-2.1

The test shall be conducted in a three-sided metal stack with an area of 305 mm^2 (12 $in.^2$) and a height of 2.13 m (84.0 in.) [*see Figure 9-2.1(a)*], with details as follows:

(a) The stack shall be supported 305 mm (12 in.) above the floor by legs and shall be open at the top and bottom.

(b) The stack shall have one open side to allow for free access of non-oxygen-depleted air to the exposed specimen during the test.

(c) The stack shall have a means for hanging the specimen as follows:

Top Specimen Rod. A steel rod 1.5 mm or 3.0 mm (0.06 in. or 0.12 in.) in diameter and 330 mm (13 in.) long, sharpened to a point at one end. The stack shall have holes of 4 mm on both sides aligned horizontally and located 1.19 m (46.8 in.) above the bottom edge of the cabinet for the location of the top specimen rod.

Bottom Specimen Rod. A steel rod 1.5 mm (0.06 in.) in diameter, 255 mm (10.0 in.) long, sharpened to a point at one end.

Vertical Guide Wires. Soft steel wire shall be used to make a pair of vertical guide wires on each side of the stack spaced 100 mm (4 in.) to the right and left of the vertical center of the stack [each pair separated by 200 mm (8 in.)]. The wires of each pair shall be 25 mm (1 in.) apart (front to back, in the cabinet).

The vertical guide wires shall be mounted using rods 6 mm (0.25 in.) in diameter fixed horizontally at the top and bottom of the stack. [*See Figure 9-2.1(g)*.]

(d) A glass fiber fabric baffle shall be installed in the upper portion of the test cabinet as follows:

1.* A piece of glass fiber fabric measuring 1 m × 125 mm (39.4 in. × 4.9 in.) shall be cut.

2. A 40-mm (1.6-in.) hem shall be sewn on each end of the fabric using a glass sewing thread.

3. A 3-mm × 330-mm (0.12-in. × 13-in.) rod shall be inserted through the hem at one end and through holes [4 mm (0.158 in.)] in the top middle of the two opposite sides of the cabinet. These holes shall be centered 10 mm ± 1 mm (0.4 in. ± 0.04 in.) below the top edge of the cabinet and midway between the front and back of the cabinet.

4. A 3-mm × 330-mm (0.12-in. × 13-in.) rod shall be inserted through the bottom hem of the glass fabric and also through the slotted holes that are in the opposite sides of the test cabinet centered 930 mm ± 2 mm (36.6 in. ± 0.08 in.) below the top of the cabinet. These slotted holes shall be 4 mm × 25 mm (0.16 in. × 1.0 in.), rounded at each end.

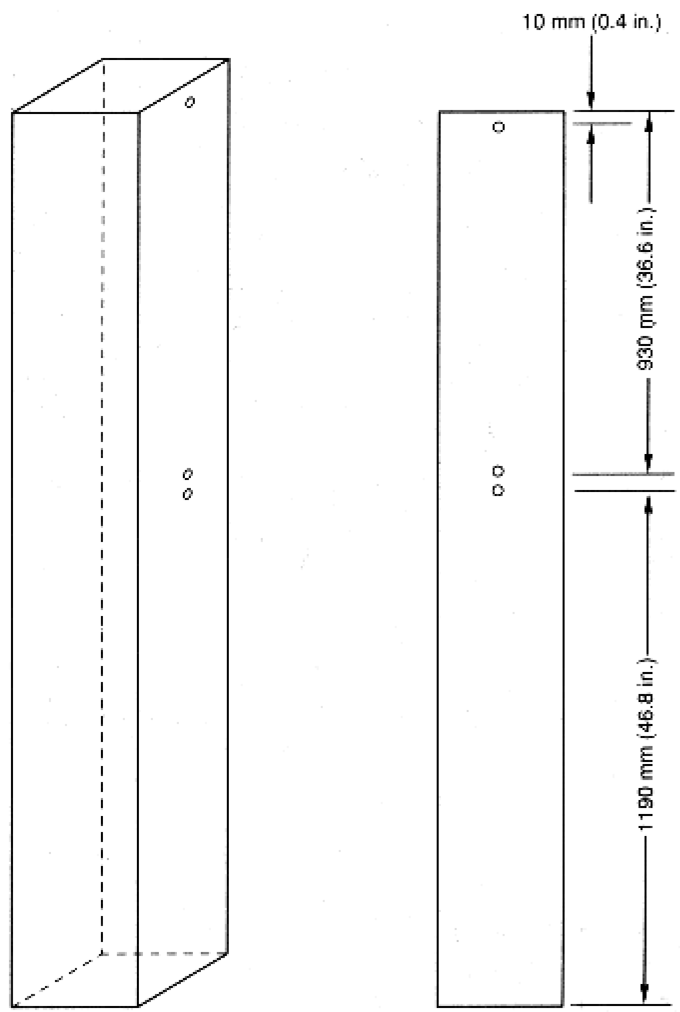


Figure 9-2.1(a) Orthographic view of test cabinet for Test 2.

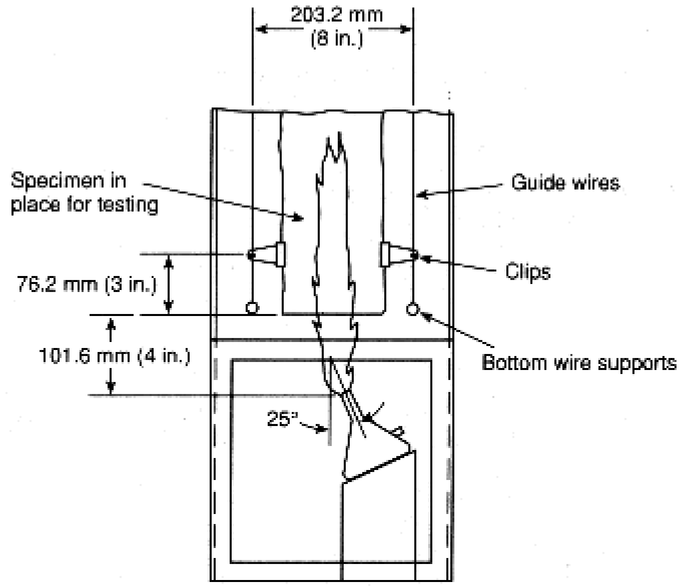


Figure 9-2.1(b) View of inside at bottom of cabinet.

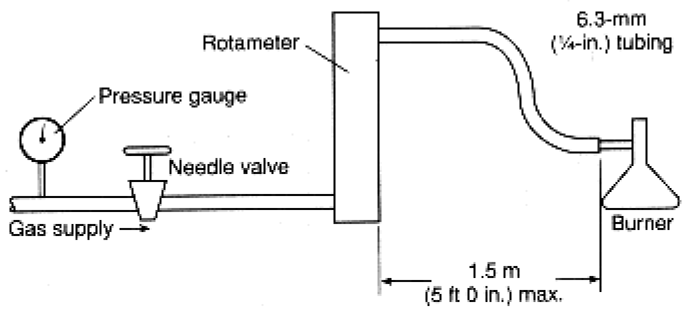


Figure 9-2.1(c) Gas line feed arrangement to burner.

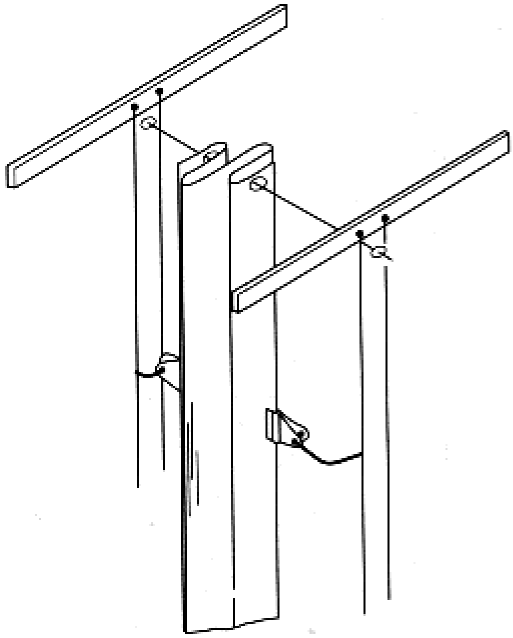


Figure 9-2.1(d) Test sample in folds.

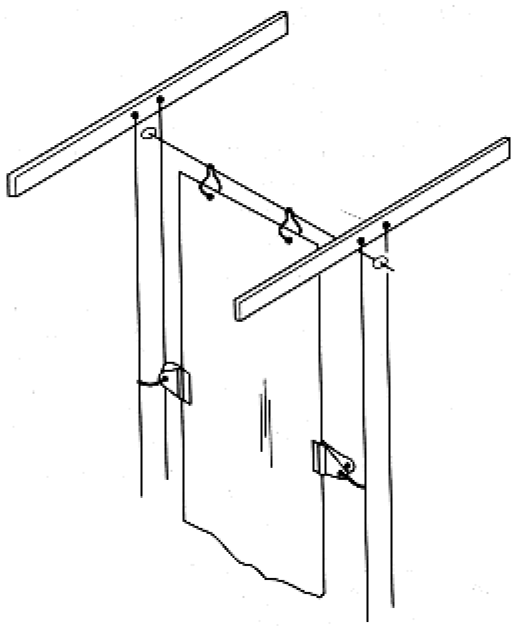


Figure 9-2.1(e) Test sample flat sheet.

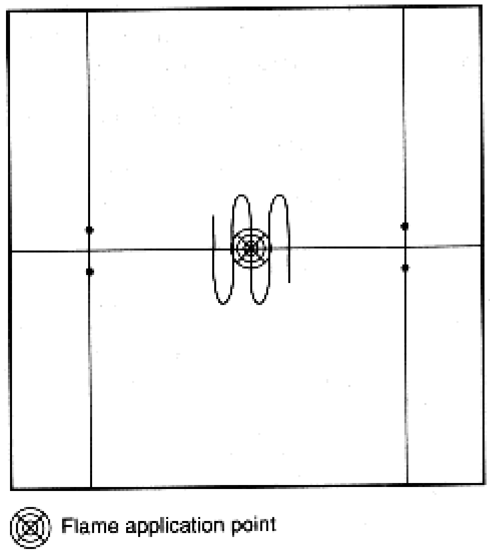


Figure 9-2.1(f) Bottom view of folded sample.

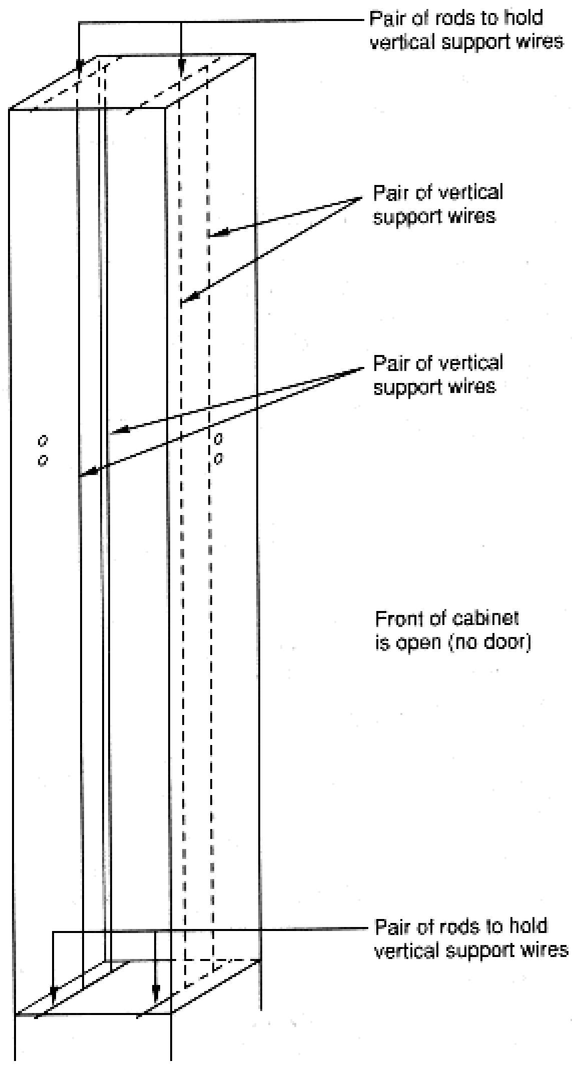


Figure 9-2.1(g) Vertical guide support.

9-2.2

The stack shall be located in a room, chamber, or hood where the temperature is 15°C ± 10°C (60°F ± 18°F) and the relative humidity does not exceed 70 percent.

9-2.3

The test chamber shall be free of drafts that affect the stability of the flame.

9-2.4

Figures 9-2.1(a) through (f) shall be used for details regarding enclosure construction and facilities for mounting both flat and folded test specimens.

9-3 Restraining Clamps.

See 11-2.3.

9-4* Gas Burner.

A bunsen burner of 9.5-mm (0.375-in.) tube diameter shall be used for the ignition source. If the burner is equipped with a gas flow controlling valve, the valve shall be open fully in order to prevent restriction of gas flow. The art vents shall be kept closed and sealed.

9-4.1

The burner shall be fixed in a position so that the barrel is at a 25-degree angle with the vertical, with the upper tip of the burner located 100 mm (4 in.) below the bottom edge of the test specimen.

9-4.2

The gas supply to the burner shall be at least 97 percent pure methane or manufactured or natural gas having a heat value of 25×10^6 J/m^3 to 31×10^6 J/m^3 (800 Btu/ft^3 to 1000 Btu/ft^3).

9-4.3

A needle valve for gas flow control shall be used followed by a rotameter in the gas line leading to the burner. The upper limit of the rotameter shall be 150 L/hr to 300 L/hr (1.47×10^{-3} ft^3/sec to 2.9×10^{-3} ft^3/sec). A pressure gauge shall be located between the gas supply and the needle valve used for controlling the gas flow. The gas lines from the needle valve to the rotameter and from the rotameter to the burner shall have a bore of at least 6 mm (0.24 in.) and shall not exceed a total length of 1.5 m (60 in.). [*See Figure 9-2.1(c).*]

9-5 Timer.

A stopwatch or other timing device that measures to an accuracy of 0.5 second shall be used for determining afterflame of burning specimens and the flame time of portions of residues that break away or drip from the test specimen and continue to flame after reaching the floor of the test chamber.

9-6 Ruler.

A ruler marked in 1-mm ($^1/_{32}$-in.) increments shall be used to measure the burner flame height and specimen dimensions.

Chapter 10 Specimens and Conditioning for Test 2

10-1 Test Specimens.

10-1.1

Selvages shall be removed from the material to be evaluated before cutting and conditioning specimens. The test specimens shall be taken from widely separated and symmetrically located sections over the entire area of the material. The specimens shall be cut on their long dimension in the lengthwise direction of the material.

10-1.2

For conducting flame tests of flat sheet materials, at least 10 specimens, 125 mm × 1.20 m ± 25 mm (4.9 in. × 47.25 in. ± 1.0 in.) shall be used. Only those specimens that cannot be folded shall be tested in the flat configuration.

10-1.3

For conducting flame tests of materials hung in folds, at least four specimens, 610 mm ± 25 mm × 1.20 m ± 25 mm (24.0 in. ± 1.0 in. × 47.25 in. ± 1.0 in.), shall be used. Each specimen shall be folded longitudinally to form four folds so that the segment of material on each side of a fold uniformly measures 125 mm ± 20 mm (4.9 in. ± 0.8 in.) in width over the length of the specimen. [*See Figures 9-2.1(d) and (f).*]

10-1.4

For multilayer assemblies (either flat or folded), the layers shall be sewn together as shown in Figure 10-1.4 using a plain stitch with 2.5 stitches/cm ± 0.25 stitch/cm (6.4 stitches/in. ± 0.6 stitch/in.). A No. 40 polyester/cotton sewing thread shall be used. The layers of the multilayer assembly shall be sewn along all four edges at a distance of 5 mm ± 1 mm (0.2 in. ± 0.04 in.) from the edge. A fifth seam shall be sewn along the center of the assembly in the lengthwise direction. This center seam shall extend the full length of the specimen. The seam shall be within 10 mm (0.4 in.) of the center of the specimen and shall continue for a distance within 300 mm (12 in.) of the lower end of the specimen.

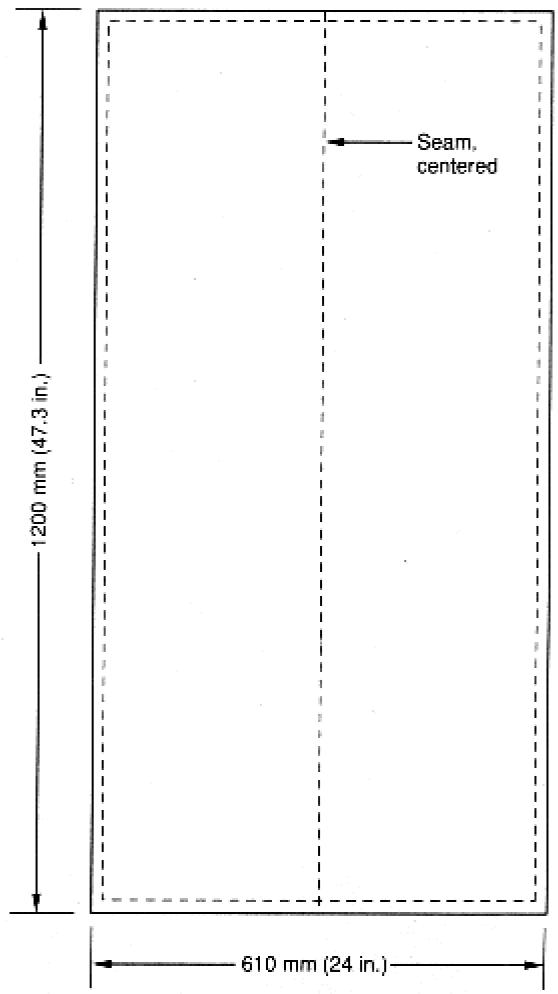


Figure 10-1.4 Multilayer specimen for Test 2.

10-2 Conditioning of Test Specimens.

10-2.1

The test specimens shall be conditioned in an oven at a temperature of 105°C ± 3°C (220°F ± 5°F) for not less than 1 hour nor more than 3 hours before testing.

10-2.2

Each specimen shall be removed from the oven no earlier than 2 minutes before igniting the gas burner.

Chapter 11 Flame Test Procedures for Test 2

11-1 Mounting of Test Specimens.

11-1.1

The 330-mm (13-in.) steel mounting rod shall be threaded through the specimen so that the folded or flat configuration, as appropriate, is maintained. The rod shall be threaded through the specimen 15 mm ± 5 mm (0.6 in. ± 0.2 in.) below the top edge of the test specimen.

11-1.1.1 The folded specimens shall be suspended vertically with the edges of the two center folds facing the front of the stack. The folds shall be spread 12 mm ± 3 mm (0.5 in. ± 0.12 in.) apart by means of the top support rod and the 1.5-mm × 255-mm (0.06-in. × 10-in.) sharpened rod shall be installed halfway down the length of the specimen to hold the folds in place. The bottom of the center portion of the section between the two middle folds shall be 100 mm ± 10 mm (4.0 in. ± 0.4 in.) above the bunsen burner.

11-1.1.2 The flat specimens shall be suspended vertically in the stack with their full width facing the front of the stack so that the center of the bottom of the specimen is located 100 mm ± 10 mm (4.0 in. ± 0.4 in.) above the bunsen burner.

11-1.2

Test specimens shall be restrained laterally at the midpoint of their length and within 75 mm (3 in.) of the bottom edge by bulldog clips and lightweight chains attached to the vertical guide wires.

11-1.3

Figures 9-2.1(d) through (f) shall be used for details for mounting test specimens.

11-2 Conducting the Flame Test.

11-2.1

The gas burner shall be ignited. The gas pressure shall be 17.5 kPa ± 2.0 kPa (2.5 psi ± 0.25 psi) with a flow rate of 113 L/hr ± 3 L/hr (1.1 × 10^{-3} ft^3/sec ± 2.9 × 10^{-5} ft^3/sec).

11-2.2

The burner air inlets shall be sealed with vinyl electrical adhesive tape to prevent the entrance of air, and the gas shall be adjusted to produce a 280-mm ± 12 mm (11-in. ± 0.5 in.) flame.

11-2.3

The position of the specimen relative to the test flame shall be maintained by using bulldog clips attached to the edges of the specimen and the vertical guide wires with lightweight chains. These clips shall be attached to the edges of the specimen at the midpoint of the specimen's length.

11-2.4

The test flame shall be applied to the specimen for 2 minutes and then shall be withdrawn.

The flame shall be applied at an angle of 25 degrees from the vertical with the burner opening 100 mm (4 in.) below the edge of the specimen and within 20 mm (0.8 in.) of the middle of the width of the lower edge of the specimen in a single sheet, or at the middle segment of folded specimens. [*See Figure 9-2.1(f).*]

11-2.5

The duration of flaming combustion of material that drops to the floor of the test chamber shall be measured to the nearest 0.5 second and recorded.

11-2.6

The duration of burning of the specimen after the igniting flame has been removed shall be measured to the nearest 0.5 second and recorded.

11-2.7

After all flaming has ceased, the test cabinet and room shall be purged prior to the next test.

11-3 Measurement of Length of Char.

The length of the char after all flaming and afterglow on the specimen has ceased shall be determined. The length of char shall be defined as the original length of the specimen minus the distance from the top edge of the specimen to the horizontal line above which all material is intact.

Chapter 12 Flame Resistance Performance Criteria for Test 2

12-1 Performance Criteria.

12-1.1

Where any specimen continues flaming for more than 2 seconds after the test flame is removed from contact with the specimen, the material shall be recorded as failing the test. (*See Section 12-2.*)

12-1.2

Where the length of char of any individual folded specimen exceeds 1050 mm (41.34 in.), the material shall be recorded as failing the test. (*See Section 12-2.*)

12-1.3

Where the char length of any single flat specimen exceeds 435 mm (40.76 in.), the material shall be recorded as failing the test. (*See Section 12-2.*)

12-1.4

Where at any time during or after the application of the test flame any portions or residues of the material being tested break or drip from the specimen and fall to the floor of the test apparatus and continue burning for more than 2 seconds after reaching the floor of the test apparatus, the material shall be recorded as failing the test. (*See Section 12-2.*)

12-2 Retest.

12-2.1

In the event that only one of the four folded specimens meets the criteria of Section 12-1, two new specimens cut in the same direction as those that failed shall be tested. If both of the new specimens fail to meet the criteria, the material shall be recorded as passing this test and shall be designated as flame resistant.

12-2.2

In the event that only one of the 10 flat specimens meets the above criteria, five new specimens cut in the same direction as the one that failed shall be tested. If all five of the new specimens fail to meet the criteria, the material shall be recorded as passing this test and shall be designated as flame resistant.

Chapter 13 Cleaning Procedures

13-1 General.

Where a manufacturer claims that the material tested in accordance with this method retains its flame resistance after cleaning or weathering, the material also shall be tested after it has been subjected to the exposure conditions specified in this section of the test method.

13-2 Application.

Each fabric shall be subjected to those exposure conditions that are applicable to its intended use (dry cleaning, laundering, or other exposure to water). Each material or assembly shall meet the flame resistance requirements of Chapters 7 and 12 after passing through the appropriate exposure cycles.

13-3 Accelerated Dry Cleaning.

13-3.1

Where the material to be tested is intended to be refurbished by dry cleaning, the material shall be subjected to three full cycles of one of the following dry-cleaning procedures:

(a) A dry-cleaning procedure specified by the manufacturer or finisher for the routine care of the material. If such care instructions are provided by the manufacturer, they shall be used; or

(b) Conventional commercial dry cleaning using either perchloroethylene or Stoddard solvent as the cleaning medium.

13-3.2

Test specimens shall be cut from the dry-cleaned material for testing.

13-3.3

The specimens shall be conditioned before testing.

13-4 Accelerated Laundering.

13-4.1

Where the material to be tested is intended to be refurbished by laundering, the material shall be subjected to five full cycles of one of the following laundering procedures:

(a) A laundering procedure specified by the manufacturer or finisher for the routine care of the material;

(b) Conventional commercial laundering; or

(c) The home laundering procedure specified in the AATCC Technical Manual, *Standard Laboratory Practice for Home Laundering Fabrics Prior to Flammability Testing to Differentiate Between Durable and Non-Durable Finishes*.

13-4.2

Test specimens cut from laundered material shall be used for testing.

13-4.3

The specimens shall be conditioned before testing.

13-5 Accelerated Water Leaching.

13-5.1

Where the material is expected to be suitable for use outdoors, the material shall be immersed totally in a vessel containing tap water at room temperature (20°C ± 5°C) (68°F ± 9°F) for not less than 72 hours. A vessel with a capacity of at least 15.1 L (4 gal) shall be used.

13-5.2

The water shall be drained from the vessel at 24-hour intervals during the immersion period. After all water has drained from the vessel, it shall be refilled as done initially.

13-5.3

At the conclusion of the immersion period, the sample shall be removed from the vessel and dried at room temperature.

13-5.4

Test specimens cut from leached material shall be used for testing.

13-5.5

The specimens shall be conditioned before testing.

13-5.6

Where the material is subjected to the accelerated laundering prescribed in Section 13-4, this leaching procedure shall not be required.

13-6 Accelerated Weathering.

13-6.1

Where limitations imposed by the weathering equipment make it possible to expose only the specimen for Test 1, the following procedure then shall be performed:

(a) The specimens for Test 1 shall be cut before the accelerated weathering procedure is performed.

(b) The specimens shall be exposed for 100 hours using the apparatus and procedure specified in AATCC Test Method 111A, *Weather Resistance: Sunshine Arc Lamp Exposure with Wetting*.

(c) The specimens shall be conditioned before testing.

Chapter 14 Reporting

14-1 General.

The recorded results shall be reported along with the description of the materials tested, test conditions, and the accelerated refurbishing or weathering treatments used (if any).

14-2 Material Description.

14-2.1

The composition and form of the material that was tested shall be described. The description shall include the manner in which the material was assembled. Where flame retardants have been added, they shall be described along with the method of application. The weight and construction of the material in the description shall be included.

14-2.2

The intended application of the material or assembly shall be included, where known.

14-3 Test Conditions.

The test used and the test conditions shall be described.

14-4 Refurbishing or Weathering Conditions.

Where any refurbishing or accelerated weathering procedures were applied to the sample, the procedures shall be described along with the number of cycles used.

14-5 Test Results.

The results from individual specimens as well as the sample average for the following measurements and observations shall be reported:

(a) The time of burning for any material that falls to the bottom of the test chamber to the nearest 0.5 second;

(b) The mass of each specimen (to the nearest g) before and after exposure to the ignition flame (Test 1);

(c) The char length to the nearest 3 mm (0.12 in.) (Test 2);

(d) The afterflame time to the nearest 0.5 second (Test 2);

(e) Any unusual behavior of specimens and other observations.

14-6 Final Conclusion.

The report shall specify whether the material passes or fails the test based on the test results and the criteria of Chapter 7 or 12, whichever is appropriate. If the material passes the test, the report shall specify that the material is flame resistant.

Chapter 15 Referenced Publications

15-1

The following documents or portions thereof are referenced within this standard and shall be considered part of the requirements of this document. The edition indicated for each reference is the current edition as of the date of the NFPA issuance of this document.

15-1.1 NFPA Publication.

National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.

NFPA 255, *Standard Method of Test of Surface Burning Characteristics of Building Materials*, 1996 edition.

15-1.2 Other Publications.

15-1.2.1 AATCC Publications. American Association of Textile Chemists and Colorists, P.O. Box 12215, Research Triangle Park, NC 27709.

AATCC Test Method 111A, *Weather Resistance: Sunshine Arc Lamp Exposure with Wetting*, 1990.

AATCC Technical Manual, *Standard Laboratory Practice for Home Laundering Fabrics Prior to Flammability Testing to Differentiate Between Durable and Non-Durable Finishes*, 1994.

Appendix A Explanatory Material

This Appendix is not a part of the requirements of this NFPA document but is included for informational purposes only.

A-2-4.2

A suitable alternate test cabinet that does not require a separate hood, equipped with a pin bar, burner-mounting system, gas control system, and timers is available as Model HVUL from Atlas Electric Devices, 4114 North Ravenswood Ave., Chicago, IL 60613; telephone (312) 327-4250.

A-2-4.3

A suitable burner is available as Catalog No. 03-902 from Fisher Scientific Co., 711 Forbes Ave., Pittsburgh, PA 15219-4785; telephone (412) 562-8300.

A-2-5.1

A suitable pressure gauge is available as Catalog No. 11-281B (0-300 mm Hg) from Fisher Scientific Co., 711 Forbes Ave., Pittsburgh, PA 15219-4785; telephone (412) 562-8300.

A-2-5.2

A suitable gas flow gauge for maintaining and monitoring the gas flow rate is available as Catalog No.N 03229-19 from Cole-Parmer Instrument Co., 7425 North Oak Park Ave., Chicago, IL 66048-9930; telephone (800) 323-4340.

A-2-10

A suitable brush can be obtained as Catalog No. 03-685 from Fisher Scientific Co., 711 Forbes Ave., Pittsburgh, PA 15219-4785; telephone (412) 562-8300.

A-9-2.1(d)1 A suitable glass fabric is Style 2116, available from Clark Schwebel Fiber Glass Corp., P.O. Box 2627, Anderson, SC 29622.

A-9-4

A suitable burner is available as Catalog No. 03-917 from Fisher Scientific Co., 711 Forbes Ave., Pittsburgh, PA 15219-4785; telephone (412) 562-8300.

Appendix B Test 1 Information

This Appendix is not a part of the requirements of this NFPA document but is included for *informational purposes only.*

B-1 Specimen Mounting Jig for Test 1.

B-1.1

Figure B-1.1 shows the construction details for a mounting jig, which makes it quicker, easier, and safer to mount the specimens for Test 1 onto the pin bar correctly.

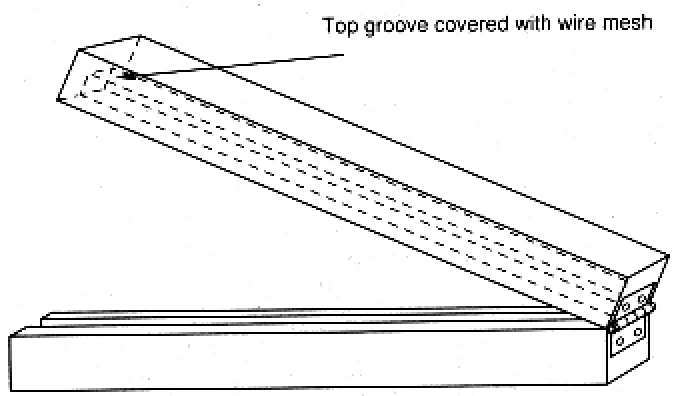


Figure B-1.1 Mounting jig for Test 1 specimens.

B-1.2

With the pin bar placed in the slot of the long arm of the jig, the specimen should be held so that the top seam of composite specimens [or an imaginary line 5 mm (0.196 in.) below the top edge of single-layer specimens] is aligned with the pins on the pin bar. The short arm of the jig then should be lowered over the pins and gently pushed downward. This secures the specimen to the pin bar. The short arm then should be raised and the pin bar, with the specimen attached, should be removed from the jig and mounted on the pin bar holder that is attached to the upper back panel of the test chamber. When in place, the pins of the pin bar should face the open side of the chamber (i.e., toward the operator).

B-2 History and Background.

B-2.1

In the past, curtain and drapery fabrics have been evaluated for their flammability characteristics primarily using the NFPA 701 test (1977 and 1989 editions), which has demonstrated a failure common to all similar tests that include a small-scale test using a mounting frame for the specimen. This failure occurs when thermoplastic products are tested. Thermoplastic tends to melt and pull away from the flame. Frequently, the thermoplastic melts and spills over and onto the frame, carrying some residual flame with it. When the test material and flame reach the frame, the frame acts as a wick and allows the material to continue burning for an extended time. Sometimes the flame self-extinguishes shortly after reaching the frame. At other times, the frame acts as a candle wick and allows the flame to continue to consume test material. In any event, thermoplastics frequently fail the afterflame criterion and sometimes the char length criterion as well.

B-2.2

In the past, NFPA 701 did permit the operator to test such thermoplastic materials using the large-scale test, which does not involve any sort of frame. In most cases, thermoplastic materials that failed the small-scale test using a frame would pass the large-scale test. This caused a problem because:

(a) More testing was needed for thermoplastic materials;

(b) Much more material was needed for the large-scale test; and

(c) The large-scale test is much more expensive to perform.

Furthermore, some regulatory jurisdictions required that materials pass both tests.

B-2.3

During the 1980s considerable effort was expended to modify the NFPA 701 tests and to arrive at pass/fail criteria for the small-scale test that would agree more closely with the results obtained with the large-scale test. During this time, a series of tests involving multilayer composites was performed at Southwest Research Institute by Belles and Beitel.

B-2.4

The tests by Belles and Beitel primarily involved combinations of materials, each of which passed the NFPA 701 small-scale test. The tests were performed on full-scale draperies hung close to a gypsum board wall, which was set up to be freestanding in a very large test room. A gypsum board ceiling extended out over the draperies for a distance of about 1 m (3.28 ft). The ignition source was a 280-mm (11-in.) flame from a bunsen burner. In order to ensure the validity of the test, the ignition flame was allowed to burn for 5 minutes.

B-2.5

These tests demonstrated, in general, that draperies consisting of face and lining materials made from the same type of fiber were less likely to propagate flame extensively. Also, draperies consisting of face and lining fabrics made from dissimilar materials were very likely to propagate flame extensively and to be destroyed almost totally in less than 2 minutes. The only exception to these results were draperies consisting of face and lining materials made from cotton with nondurable, flame-resistant treatments. In these cases, the fabric tended to resist the flame for 2 minutes to 3 minutes and then to ignite and burn intensely. Since NFPA 701 is intended to evaluate fabrics for relatively short exposures to the flame, such fabrics generally pass NFPA 701 tests.

B-2.6

In any event, these tests demonstrated a serious weakness in the NFPA 701 test, since the same combinations of fabrics that propagated the flames extensively in the SwRI tests performed well in both the NFPA 701 large- and small-scale tests. This led the fiber and textile industry trade associations to work closely with NFPA, ASTM, and the Center for Fire Research at the National Institute for Science and Technology to implement a program to develop a new test that would evaluate both single-layer fabrics as well as multilayer composites, such as draperies for flame resistance, in a small-scale test that adequately predicts the results obtained at SwRI.

B-2.7

The first phase of work at NIST confirmed the results of the SwRI tests and also showed that existing small-scale tests did not predict the SwRI results.

B-2.8

The second phase resulted in the Test 1 method. Subsequent to the work at NIST, there has been some refinement of the test method as well as much verification testing. The Test 1 method, as presented here, does not reproduce the SwRI results precisely, since combinations that burned nearly completely (at least 95 percent destruction) in the SwRI tests showed a weight loss of approximately only 80 percent in this test. Nevertheless, the “good” performers at SwRI showed a weight loss of less than 40 percent in this test and the “bad” performers at SwRI showed a weight loss of greater than 40 percent. The one exception is vinyl-coated fabric blackout linings, which behave in a very inconsistent manner. Consequently, these linings and lined draperies containing such materials should be tested using Test 2, the large-scale test.

B-2.9

During the development of the Test 1 method, another test method was tried and eventually abandoned because of the cost of the apparatus and potential operator safety problems. This alternative test method was based on an analysis of the differences between the room-scale test and the NFPA 701 test. It was observed in the room-scale tests that flames usually propagated more rapidly on the portion of the specimen that faced the wall. This suggested that the radiant energy reflected back to the specimen by the wall was critical. In order to simulate this situation in a test cabinet such as the one used in the NFPA 701 test, it seemed appropriate to heat the back wall of the cabinet so that it would radiate heat to the back surface of the specimen. Consequently, a cabinet was equipped with electrical strip heaters mounted on a 1-cm (0.39-in.) aluminum plate that, in turn, was attached to the back of the cabinet. The remainder of the test was identical to ASTM D 3659, *Standard Test Method for Flammability of Apparel Fabrics by Semi-Resistant Method*. Back surface temperatures in excess of 240°C (465°F) were needed to duplicate the SwRI results. The quoted cost of a test chamber modified for ASTM D 3659 is $3000. The additional modification for heating the back wall surface was estimated at an additional $3000 for a total cost for the test chamber of approximately $6000. This cost would prevent many laboratories from participating in the interlaboratory test required to validate the test. For this reason, as well as the possibility of operators sustaining burns when placing and removing specimens, this alternative method was abandoned.

B-2.10

The present test method eliminates the need for heating the back surface by placing the specimen very close to the back surface. This tends to form a chimney that funnels the heat between the wall and the specimen. This heats the back wall, which, in turn, reradiates some of the heat onto the back surface of the specimen.

Appendix C Textile Considerations

This Appendix is not a part of the requirements of this NFPA document but is included for informational purposes only.

C-1 General Considerations.

C-1.1

While it is not possible to make combustible textiles and films completely resistant to charring and decomposition when exposed to flame or high temperature, a degree of flame resistance can be achieved. Most natural and synthetic fiber textiles can be treated chemically to increase their flame resistance. Such treatments might be fugitive and, hence, not durable to laundering, dry cleaning, or water leaching, while other treatments are very durable and can withstand many cycles of laundering, dry cleaning, or water leaching. Furthermore, some synthetic fibers are made from polymers that contain flame retardants in their basic structure. Both approaches could be necessary to impart flame resistance to materials in which different types of fibers are blended. It should be noted, however, that combinations of flame-resistant (FR) fibers with relatively small percentages of non-flame-resistant fibers can interfere with the flame-resistant effect of the FR fibers.

C-1.2

The hazards introduced by combustible textiles might, of course, be avoided entirely where the use of such noncombustible fibers as glass is practical.

C-1.3

Many flame-resistant synthetic materials soften and melt when exposed to heat and fire. They also can be subject to twisting, shrinking, dripping, and elongation when subjected to fire conditions.

C-2 Applications of Flame-Resistant Fabrics.

C-2.1

Standards for theater scenery, curtains, and furnishings in high risk or assembly occupancies are commonly set by law.

Flame-resistant fabrics are used in hotels, hospitals, and similar occupancies in the interest of the preservation of lives and property from fire.

C-2.2

Flame-resistant fabrics also are used as work clothing in industries where exposure to heat, open flames, and flash fire is a possibility.

C-2.3

Fabrics treated for flame and weather resistance are used for tents, tarpaulins, and other outdoor protective covering.

C-2.4

Reinforced plastic films with flame-resistant qualities are used in membrane structures.

C-2.5

Transparent plastic films often are used as a temporary enclosure for greenhouses and for construction work.

C-3 Flame-Retardant Treatments.

C-3.1

An increasing range of flame-retardant treatments for natural and synthetic fiber materials is becoming available. The selection of a particular treatment is governed by the intended use of the treated fabric.

C-3.2

Topical treatments based on water-soluble chemicals are generally the least expensive and most easily applied; however, they are subject to removal by the leaching action of water in laundering, scrubbing, or exposure to weather.

C-3.3

Some treatments can be impaired by the action of the solvents used in dry cleaning, and some gradually can lose their effectiveness under conditions of storage and usage not involving leaching.

C-3.4

Relatively temporary treatments are suitable only where proper treatment renewal can be ensured or for decorations and other items that are used briefly and then discarded.

C-3.5

Situations where retreatment is uncertain or not feasible indicate the choice of one of the durable treatments that is suitable for clothing and decorative fabrics. A number of these treatments can withstand extensive laundering and dry cleaning, although they are higher in cost and should be applied professionally.

C-3.6

For outdoor use, treatments have been developed that can be expected to remain effective for the useful life of the fabric under normal conditions of weather exposure.

C-3.7

It should be noted that painting or coating a treated or flame-resistant fabric or film could impair its flame-resistant qualities unless the coating itself is flame-resistant.

C-4 Physical Properties of Treated Fabrics.

C-4.1

A number of factors, which vary in importance depending on the end use of the fabric, should be considered in selecting a flame-retardant treatment.

C-4.2

The effect on the appearance, texture, and flexibility of the fabric often is of primary concern.

Appendix D Bibliography

This Appendix is not a part of the requirements of this NFPA document but is included for informational purposes only.

Arnold, G., Fisher, A., and Frohnsdorff, G. “Gillette Research Institute Final Report” (March 26, 1973), abstracted in the *Proceedings of the 1974 International Symposium on Flammability* *and Fire Retardants* (Editor: V.M. Bhatnager), Technomic Publishing Company, Lancaster, PA 17604.

Belles, D. W. and Beitel, J. J. “Do Multi-Layer Draperies Pass the Single-Layer Fire Test?” *Fire Journal*, September October 1988, Vol. 82, No. 5, pp. 25-30, 90-91.

Krasny, J. F. and Fisher, A. L. “Laboratory Modeling of Garment Fires,” *Textile Research Journal*, 1973, Vol. 43, pp. 272-283.

McCullough, E. A. and Noel, C. J. “Flammability Characteristics of Layered Fabric Assemblies,” in *Proceedings of the 12th Annual Meeting, Information Council on Fabric Flammability*, 1978, pp. 175-184.

Appendix E Referenced Publications

E-1

The following document or portions thereof is referenced within this standard for informational purposes only and thus is not considered part of the requirements of this document. The edition indicated for the reference is the current edition as of the date of the NFPA issuance of this document.

E-1.1 ASTM Publication.

American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103.

ASTM D 3659, *Standard Test Method for Flammability of Apparel Fabrics by Semi-Resistant Method*, 1993.

Tentative Interim Amendment

NFPA 701 Figure B-1.1

Standard Methods of Fire Tests for Flame-Resistant Textiles and Films

1996 Edition

Reference: 1-1.7, A-1-1.7(New)
TIA 96-1 (NFPA 701)

Pursuant to Section 4 of the NFPA Regulations Governing Committee Projects, the National Fire Protection Association has issued the following Tentative Interim Amendment to NFPA 701, *Standard Methods of Fire Tests for Flame-Resistant Textiles and Films*, 1996 edition. The TIA was processed by the Technical Committee on Fire Tests, and was issued by the Standards Council on January 12, 1996, with an effective date of February 1, 1996.

A Tentative Interim Amendment is tentative because it has not been processed through the entire standards-making procedures. It is interim because it is effective only between editions of the standard. A TIA automatically becomes a proposal of the proponent for the next edition of the standard; as such, it then is subject to all of the procedures of the standards-making process.

1. Revise 1-1.7 to read as follows:

1-1.7*

Where materials are to be applied to surfaces of buildings or backing materials as interior finishes for use in buildings, they shall be tested in accordance with the appropriate test method for that particular interior finish application.

2. Add an appendix note to read as follows:

A-1-1.7

Other tests used to evaluate interior finishes include NFPA 255, *Standard Method of Test of Surface Burning Characteristics of Building Materials*, and NFPA 265, *Standard Methods of Fire Tests for Evaluating Room Fire Growth Contribution of Textile Wall Coverings*. Additional information on interior finishes can be found in Section 6-5, NFPA 101®, *Life Safety Code*®.

NFPA 701

Standard Methods of Fire Tests for Flame-Resistant Textiles and Films

1996 Edition

Reference: A-2-4.2
TIA 96-2 (NFPA 701)

Pursuant to Section 4 of the NFPA Regulations Governing Committee Projects, the National Fire Protection Association has issued the following Tentative Interim Amendment to NFPA 701, *Standard Methods of Fire Tests for Flame-Resistant Textiles and Films*, 1996 edition. The TIA was processed by the Fire Tests Committee, and was issued with revision by the Standards Council on January 15, 1997, with an effective date of February 4, 1997.

A Tentative Interim Amendment is tentative because it has not been processed through the entire standards-making procedures. It is interim because it is effective only between editions of the standard. A TIA automatically becomes a proposal of the proponent for the next edition of the standard; as such, it then is subject to all of the procedures of the standards-making process.

1. Delete paragraph A-2-4.2 and the last parenthetical sentence in 2-4.2.

NFPA 703

1995 Edition

Standard for Fire Retardant Impregnated Wood and Fire Retardant Coatings for Building Materials

1995 Edition

This edition of NFPA 703, *Standard for Fire Retardant Impregnated Wood and Fire Retardant Coatings for Building Materials*, was prepared by the Technical Committee on Building Construction and acted on by the National Fire Protection Association, Inc., at its Annual Meeting held May 22-25, 1995, in Denver, CO. It was issued by the Standards Council on July 21, 1995, with an effective date of August 11, 1995, and supersedes all previous editions.

This edition of NFPA 703 was approved as an American National Standard on August 11, 1995.

Origin and Development of NFPA 703

In 1957, the Committee on Flameproofing and Preservative Treatments began to develop a standard for flameproofing of wood. It soon became clear to the committee that the fire retardant coating industry was expanding considerably, and that fire retardant admixtures of plastics and other building materials required coverage in the standard. Thus, in its many subsequent meetings, the Committee reexamined its approach and expanded the standard to cover all fire retardant treatments.

The standard was tentatively adopted at the 1960 Annual Meeting and was submitted for final adoption at the 1961 Annual Meeting.

The 1979 edition of NFPA 703, *Fire Retardant Impregnated Wood and Fire Retardant Coatings for Building Materials*, superseded the previous 1961 edition. The change in title was necessary to more adequately cover the subjects included in the text of the standard. The principal changes in the 1979 edition included improved definitions for fire retardant coatings.

The 1985 edition included the addition of a new Chapter 4 that listed referenced publications whose use is mandated within this standard.

In the 1992 edition, the Committee provided clarification in several areas defining fire resistance. The 1995 edition was reconfirmed with some editorial changes.

Technical Committee on Building Construction

Jack L. Kerin, *Chair*
State of California, CA
Rep. Nat'l Conference of States on Building Codes & Standards Inc.

Robert M. Berhinig, Underwriters Laboratories Inc., IL

Peter H. Billing, American Forest & Paper Assn., FL

William I. Blazek, U.S. General Services Administration, DC

John P. Chleapas, Framingham, MA

Richard J. Davis, Factory Mutual Research, MA

Alan J. Dopart, BRI Coverage Corp., NY

Elaine B. Gall, VA State Fire Marshal's Office, VA

Daniel F. Gemeny, Rolf Jensen & Assoc., Inc., CA

Richard G. Gewain, Hughes Assoc., Inc., MD

Karl D. Houser, Gypsum Assn., DC

Harlan C. Ihlenfeldt, Kemper Nat'l Insurance Cos., IL

Timothy J. Matey, Entergy Operations Inc., LA

Daniel M. McGee, American Iron & Steel Inst., NJ

Joseph J. Messersmith, Portland Cement Assn., VA

Brad Schiffer, Brad Schiffer/Taxis, Inc., FL

Raymond S. Szczucki, CIGNA Loss Control Services, PA
Rep. American Insurance Services Group, Inc.

Lyndon Welch, Ann Arbor, MI

Peter J. Gore Willse, Industrial Risk Insurers, CT

Alternates

Kenneth E. Bland, American Forest & Paper Assn., NH
(Alt. to P. H. Billing)

Donald J. Boehmer, Rolf Jensen & Assoc., Inc., IL
(Alt. to D. F. Gemeny)

David W. Frable, U.S. General Services Administration, DC
(Alt. to W. I. Blazek)

Todd E. Schumann, Industrial Risk Insurers, IL
(Alt. to P. J. G. Willse)

Stephen V. Skalko, Portland Cement Assn., GA
(Alt. to J. J. Messersmith)

Dean J. Tills, American Iron Steel Inst., DC
(Alt. to D. M. McGee)

Steven F. Sawyer, NFPA Staff Liaison

This list represents the membership at the time the Committee was balloted on the text of this edition. Since that time, changes in the membership may have occurred.

NOTE: Membership on a Committee shall not in and of itself constitute an endorsement of the Association or any document developed by the Committee on which the member serves.

Committee Scope: This Committee shall have primary responsibility for documents on the design, installation and maintenance of building construction features not covered by other NFPA committees. (This Committee does not cover building code requirements, exits, protection at openings, vaults, air conditioning, blower systems, etc., which are handled by other committees.)

NFPA 703
Standard for
Fire Retardant Impregnated Wood and Fire Retardant Coatings for Building Materials

1995 Edition

NOTICE: An asterisk (*) following the number or letter designating a paragraph indicates explanatory material on that paragraph in Appendix A.
Information on referenced publications can be found in Chapter 4 and Appendix B.

Chapter 1 General

1-1* Scope.

This standard provides criteria for defining and identifying fire retardant impregnated wood and fire retardant coated building materials.

1-2 Definitions.

Authority Having Jurisdiction.* The organization, office, or individual responsible for approving equipment, an installation, or a procedure.

Labeled. Equipment or materials to which has been attached a label, symbol, or other identifying mark of an organization that is acceptable to the authority having jurisdiction and concerned with product evaluation that maintains periodic inspection of production of labeled equipment or materials and by whose labeling the manufacturer indicates compliance with appropriate standards or performance in a specified manner.

Chapter 2 Fire Retardant Impregnated Wood

2-1 Application.

These requirements shall apply to pressure impregnation treatments that reduce certain burning characteristics of wood. Pressure impregnated lumber and plywood shall be treated for fire retardance in accordance with the requirements of the American Wood Preservers' Association Standard C1, *All Timber Product-Preservative Treatment by Pressure Process*, as modified herein. Other approved methods of impregnation of wood products providing at least equal performance shall also be considered acceptable.

2-2 Results of Treatment — All Species.

2-2.1 Conditions of Material.

2-2.1.1 Moisture Content. Subsequent to treatment, fire retardant treated lumber and plywood shall be air-dried or kiln-dried to an average moisture content of 19 percent or less for lumber and 15 percent or less for plywood in accordance with end-use requirements.

2-2.1.1.1 Air-Drying. Where material is air dried it shall not be exposed to conditions that could cause chemicals to leach out.

2-2.1.1.2 Kiln-Drying. During kiln-drying the dry bulb temperature of the kiln shall not exceed 16°F until the average moisture content of the wood has dropped to 25 percent or less.

2-2.2 Performance Rating.

2-2.2.1 Fire Hazard Classification. Material shall have a flame spread index of 25 or less with no evidence of significant progressive combustions when tested for 30 minutes by the test listed in Section 2-3. In addition, the flame front shall not progress more than 10.5 ft beyond the center line of the burner at any time during the test.

2-2.2.2 Interior Type A. Where experience demonstrates a specific need for the use of materials with low hygroscopicity, material shall have an equilibrium moisture content of not more than 28 percent when tested in accordance with the procedures in ASTM D3201, *Standard Test Method for Hygroscopic Properties of Fire-Retardant Wood and Wood-Base Products*, at 92 ± 2 percent relative humidity.

2-2.2.3 Interior Type B. Where experience demonstrates no specific need for the use of material with low hygroscopicity, the material shall have an equilibrium moisture content of not more than 28 percent when tested in accordance with the procedures in ASTM D3201, *Standard Test Method for Hygroscopic Properties of Fire-Retardant Wood and Wood-Base Products*, at 78 ± 2 percent relative humidity.

2-2.2.4 Exterior Type. Where material is to be used outdoors and subjected to rainfall or sustained humidity of 80 percent or more, the material shall show no increase in flame spread index when subjected to the standard rain test described in ASTM D2898, *Standard Methods for Accelerated Weathering of Fire Retardant-Treated Wood for Fire Testing* – Method A.

2-3* Tests.

Fire retardant treated wood shall be tested in accordance with NFPA 255, *Standard Method of Test of Surface Burning Characteristics of Building Materials.*

2-4 Inspection and Identification.

Inspection shall be required by an independent and qualified test agency that establishes the requirements for treatment relative to the preceding requirements. All fire retardant treated wood products shall be labeled by the testing agency certifying such ratings.

2-5 Exposure.

Design criteria for fire retardant impregnated wood shall take into consideration the temperature and humidity conditions to which the material will be exposed.

Chapter 3 Fire Retardant Coatings for Building Materials

3-1 Application.

These requirements shall apply to fire retardant coatings such as paints and other surface coatings used to reduce certain burning characteristics of building materials.

3-2 Definitions.

Fire Retardant Coating. A coating that reduces the flame spread of Douglas Fir, and all other tested combustible surfaces to which it is applied, by at least 50 percent or to a flame spread classification value of 75 or less, whichever is the lesser value, and has a smoke developed rating not exceeding 200.

Class A Fire Retardant Coating. As applied to building materials, shall reduce the flame spread to 25 or less, and have a smoke developed rating not exceeding 200.

Class B Fire Retardant Coating. As applied to building materials, shall reduce the flame spread to greater than 25 but not more than 75, and have a smoke developed rating not exceeding 200.

3-3 General.

3-3.1

Fire retardant coatings shall remain stable and adhere to the material under all atmospheric conditions the material is exposed to.

3-3.2

A fire retardant coating shall not be used for unprotected outdoor installations unless labeled for such installations.

3-3.3

The classification of fire retardant coatings is applicable only when the coating is applied at the rates of coverage and to the type or kind of surfaces indicated on the test report when the coating is applied in accordance with the manufacturer's directions supplied with the container.

3-3.4

These coatings shall be applied in accordance with the manufacturer's direction.

3-3.5

The authority having jurisdiction might require that the application be certified by the applicator as being in conformance with the manufacturer's direction for application.

3-3.6

A fire retardant coating shall not be overcoated with any material unless both the fire retardant coating and the overcoat have been tested as a system and are found to meet the requirements of a fire retardant coating.

3-4 Tests.

3-4.1*

Fire retardant coatings shall be tested by NFPA 255, *Standard Method of Test of Surface Burning Characteristics of Building Materials*.

3-4.2

Where fire retardant coatings are to be subjected to sustained humidity of 80 percent or more or exposure to the weather, certification by a testing laboratory must indicate that there is no increase in listed classification when subjected to the "Standard Rain Test" described in ASTM D2898, *Standard Methods for Accelerated Weathering of Fire Retardant-Treated Wood for Fire Testing.*

3-5 Maintenance of Protection.

Fire retardant coatings shall possess the desired degree of permanency and shall be maintained to retain the effectiveness of the treatment under the service conditions encountered in actual use.

3-6 Identification.

Each container of fire retardant coating material shall be labeled to indicate conformance with the preceding requirements and shall include the manufacturer's instructions for application.

Chapter 4 Referenced Publications

4-1

The following documents or portions thereof are referenced within this standard and shall be considered part of the requirements of this document. The edition indicated for each reference is the current edition as of the date of the NFPA issuance of this document.

4-1.1 NFPA Publication.

National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.

NFPA 255, *Standard Method of Test of Surface Burning Characteristics of Building Materials*, 1990 edition.

4-1.2 Other Publications.

4-1.2.1 ASTM Publications. American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103.

ASTM D2898, *Standard Methods for Accelerated Weathering of Fire Retardant-Treated Wood for Fire Testing*, 1981.

ASTM D3201, *Standard Test Method for Hygroscopic Properties of Fire-Retardant Wood and Wood-Base Products*, 1986.

4-1.2.2 AWPA Publication. American Wood Preservers Association, P.O. Box 286, Woodstock, MD 21163-0286.

C-1, *All Timber Product-Preservative Treatment by Pressure Process*, 1991.

Appendix A Explanatory Material

This Appendix is not a part of the requirements of this NFPA document but is included for informational purposes only.

A-1-1

Fire resistance ratings measured on an hourly basis are not covered in this standard. To establish such ratings, tests should be made in accordance with NFPA 251, *Standard Methods of Tests of Fire Endurance of Building Construction and Materials*.

A-1-2 Authority Having Jurisdiction.

The phrase “authority having jurisdiction” is used in NFPA documents in a broad manner since jurisdictions and “approval” agencies vary as do their responsibilities. Where public safety is primary, the “authority having jurisdiction” may be a federal, state, local or other regional department or individual such as a fire chief, fire marshal, chief of a fire prevention bureau, labor department, health department, building official, electrical inspector, or others having statutory authority. For insurance purposes, an insurance inspection department, rating bureau, or other insurance company representative may be the “authority having jurisdiction.” In many circumstances the property owner or his designated agent assumes the role of the “authority having jurisdiction”; at government installations, the commanding officer or departmental official may be the “authority having jurisdiction.”

A-2-3

Test methods similar to NFPA 255, *Test for Surface Burning Characteristics of Building Materials*, include UL 723, *Standard Method of Test of Surface Burning Characteristics of Building Materials*, and ASTM E84, *Standard Test Method for Surface Burning Characteristics of Building Materials.* Under the criteria of NFPA 255, the flame spread rating is expressed numerically on a scale for which the zero point is fixed by the performance of inorganic-reinforced cement board and the 100 point (approximately) is fixed by the performance of untreated red oak flooring.

A-3-4.1

The flame spread rating is expressed numerically on a scale for which the zero point is fixed by the performance of inorganic-reinforced cement board and the 100 point (approximately) is fixed by the performance of red oak flooring.

Appendix B Referenced Publications

B-1

The following documents or portions thereof are referenced within this standard for informational purposes only and thus should not be considered part of the requirements of this document. The edition indicated for each reference is the current edition as of the date of the NFPA issuance of this document.

B-1.1 NFPA Publication.

National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.

NFPA 251, *Standard Methods of Tests of Fire Endurance of Building Construction and Materials*, 1995 edition.

B-1.2 Other Publications.

B-1.2.1 UL Publication. Underwriters Laboratories Inc., 333 Pfingsten Road, Northbrook, IL 60062.

UL 723, *Test for Surface Burning Characteristics of Building Materials*, 7th edition.

B-1.2.2 ASTM Publication. American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103.

ASTM E84, *Standard Test Method for Surface Burning Characteristics of Building Materials*, 1990.

NFPA 704

1996 Edition

Standard System for the Identification of the Hazards of

1996 Edition

This edition of NFPA 704, *Standard System for the Identification of the Hazards of Materials for Emergency Response*, was prepared by the Technical Committee on Classification and Properties of Hazardous Chemical Data and acted on by the National Fire Protection Association, Inc., at its Annual Meeting held May 20-23, 1996, in Boston, MA. It was issued by the Standards Council on July 18, 1996, with an effective date of August 9, 1996, and supersedes all previous editions.

Changes other than editorial are indicated by a vertical rule in the margin of the pages on which they appear. These lines are included as an aid to the user in identifying changes from the previous edition.

This edition of NFPA 704 was approved as an American National Standard on July 26, 1996.

Origin and Development of NFPA 704

Work on this standard originated in 1957 with a great deal of the development work having been done by the NFPA Sectional Committee on Classification, Labeling and Properties of Flammable Liquids starting in 1952. Background data was published by the Association in its Quarterly magazine in July 1954, 1956, and 1958. The material in its present form was first Tentatively Adopted in 1960. Official Adoption was secured in 1961 and revisions adopted in 1964, 1966, 1969, 1975, 1980, and 1985. In the 1987 and 1990 editions, the Committee on Fire Hazards of Materials introduced quantitative guidelines for assigning the Health Hazard and Reactivity Hazard Ratings. This 1996 edition contains additional quantitative guidelines and amended definitions for the Reactivity (Instability) Hazard Ratings.

Technical Committee on Classification and Properties of Hazardous Chemical Data

F. Owen Kubias, *Chair*
Rocky River, OH

Robert A. Michaels, *Secretary*
RAM TRAC Corp., NY

Jacqueline E. Alpert, Underwriters Laboratories Inc., IL

William J. Bradford, Brookfield, CT

Laurence G. Britton, Union Carbide Corp., WV

Paul L. Errico, Ogden Services, CT

Mark I. Grossman, Reliance Nat'l Risk Specialists, NY

Ron A. Kirsch, Occupational Health Services Inc., TN

Arthur A. Krawetz, Phoenix Chemical Laboratory Inc., IL

Roland J. Land, Jardine Insurance Brokers, NY

Whitney Fay Long, Nat'l Paint & Coatings Assn., DC

Jennifer L. Nelson, AT&T Co., NJ
Rep. NFPA Industrial Fire Protection Section

Curtis G. Payne, U.S. Coast Guard (G-MTH-1), DC

Gary Robinson, Liberty Mutual Insurance Co., IL
Rep. The Alliance of American Insurers

Norman E. Scheffler, The Dow Chemical Co., MI

Norman V. Steere, Norman V. Steere Assoc., Inc., MN

Alternates

Robert A. Kingsbury, Underwriters Laboratories Inc., IL
(Alt. to J. E. Alpert)

Nonvoting

Howard H. Fawcett, Wheaton, MD
(Member Emeritus)

Richard D. Tarr, U.S. Dept. of Transportation, DC

Jan van der Linde, Samsom Chemical Publishers, Netherlands

Ira Wainless, U.S. Dept. of Labor/OSHA, DC

Guy R. Colonna, NFPA Staff Liaison

This list represents the membership at the time the Committee was balloted on the text of this edition. Since that time, changes in the membership may have occurred.

NOTE: Membership on a Committee shall not in and of itself constitute an endorsement of the Association or any document developed by the Committee on which the member serves.

Committee Scope: This Committee shall have primary responsibility for documents on the classification of the relative hazards of all chemical solids, liquids and gases and to compile data on the hazard properties of these hazardous chemicals.

NFPA 704
Standard System for the Identification of the Hazards of Materials for Emergency Response

1996 Edition

NOTICE: An asterisk (*) following the number or letter designating a paragraph indicates explanatory material on that paragraph in Appendix A.
Information on referenced publications can be found in Appendix E.

Foreword

The Committee has been working on the material in this standard since early 1957. A great deal of preliminary work was developed as a manual by the Sectional Committee on Classification, Labeling and Properties of Flammable Liquids of the NFPA Committee on Flammable Liquids starting in 1952. Progress reports were given on this activity at NFPA Annual Meetings and reported in the NFPA *Quarterly* in July issues of 1954, 1956, and 1958. The material was tentatively adopted as a guide in 1960, adopted in 1961, and further amended in 1964, 1966, 1969, 1975, and 1980.

As originally conceived, the purpose of the standard is to safeguard the lives of those individuals who respond to emergencies occurring in an industrial plant or storage location where the hazards of materials are not readily apparent.

Chapter 1 General

1-1 Scope.

1-1.1

This standard shall address the health, flammability, instability, and related hazards that are presented by short-term, acute exposure to a material under conditions of fire, spill, or similar emergencies.

1-1.2

This standard provides a simple, readily recognized and easily understood system of markings that provides a general idea of the hazards of a material and the severity of these hazards as they relate to emergency response. The objectives of the system are:

(a) To provide an appropriate signal or alert and on-the-spot information to safeguard the lives of both public and private emergency response personnel;

(b) To assist in planning for effective fire and emergency control operations, including clean-up;

(c) To assist all designated personnel, engineers, plant and safety personnel in evaluating hazards.

1-1.3

It is recognized that local conditions will have a bearing on evaluation of hazards; therefore, discussion shall be kept in general terms.

1-2 Applicability.

1-2.1

This standard is applicable to industrial, commercial, and institutional facilities that manufacture, process, use, or store hazardous materials.

1-2.2

This standard is not applicable to transportation or use by the general public.

1-2.3*

This standard is not intended to address:

(a) Occupational exposure;

(b) Explosive and blasting agents, including commercial explosive material as defined in NFPA 495, *Explosive Materials Code*;

(c) Chemicals whose only hazard is one of chronic health hazards;

(d) Teratogens, mutagens, oncogens, etiologic agents, and other similar hazards.

1-3 Purpose.

This system is intended to provide basic information to fire fighting, emergency, and other personnel, enabling them to easily decide whether to evacuate the area or to commence emergency control procedures. It is also intended to provide them with information to assist in selecting fire-fighting tactics and emergency procedures.

1-4 Description.

1-4.1

This system identifies the hazards of a material in terms of three principal categories: "health," "flammability," and "instability." The system indicates the degree of severity by a numerical rating that ranges from four (4), indicating severe hazard, to zero (0), indicating minimal hazard.

1-4.2

The information is presented by a spatial arrangement of numerical ratings with the health rating always at the nine o'clock position; the flammability rating always at the twelve o'clock position; and the instability rating always at the three o'clock position. Each rating is located in a square-on-point field, each of which is assigned a color: blue for health hazard; red for flammability hazard; yellow for instability hazard. Alternately, the square-on-point field shall be permitted to be any convenient contrasting color and the numbers themselves shall be permitted to be colored. See Figures 6-1 through 6-3 for examples of the spatial arrangements.

1-4.3

The fourth space, at the six o'clock position, is reserved for indicating any unusual reactivity with water. The standard symbol for indicating unusual reactivity with water is the letter "W" with a line through the center: W̶. No special color is associated with this symbol.

1-4.3.1 This space shall be permitted to be used to indicate other unusual hazards, but only if not needed to indicate reactivity with water. Approved symbols will be designated in Chapter 5 of this standard.

1-5 Assignment of Ratings.

1-5.1

While the system is basically simple in application, the hazard evaluation required to determine the correct numerical ratings for a specific material shall be performed by persons who are technically competent and experienced in the interpretation of the hazard criteria set forth in this standard. Assignment of ratings shall be based on factors that encompass a knowledge of the inherent hazards of the material, including the extent of change in behavior to be anticipated under conditions of exposure to fire or fire control procedures. For additional information, see NFPA 49, *Hazardous Chemicals Data*, and NFPA 325, *Guide to Fire Hazard Properties of Flammable Liquids, Gases, and Volatile Solids*.

1-5.2

The system is based on relative rather than absolute values. Therefore, it is anticipated that conditions of storage and use can result in different ratings being assigned to the same material by different persons. Furthermore, the guidance presented in the following chapters is necessarily limited. For example, flash point is the primary criterion for assigning the flammability rating, but other criteria might be of equal importance. For example, autoignition temperature, flammability limits, and susceptibility of a container to failure due to fire exposure also shall be considered. For instability, emphasis has been placed on the ease by which an energy-releasing reaction is triggered. For health, consideration shall be given not only to inherent hazards but also to protective measures that shall be taken to minimize effects of short-term exposure.

1-5.3

In some situations, such as warehouses, storage rooms or buildings, laboratory facilities, etc., a variety of materials can be present in one localized area. In such cases considerable judgment might be needed to properly assign ratings to the area.

1-5.4

Based upon professional judgment it shall be permitted to either increase or decrease the hazard rating to more accurately assess the likely degree of hazard that will be encountered.

Chapter 2 Health Hazards

2-1 General.

2-1.1

This chapter shall address the capability of a material to cause personal injury due to contact with or entry into the body via inhalation, ingestion, skin contact, or eye contact. Only the hazards that arise from an inherent toxic property of the material or its products of decomposition or combustion shall be considered. Injury resulting from the heat of a fire or from the force of an explosion shall not be considered.

2-1.2

In general, the health hazard that results from a fire or other emergency condition is one of acute (single) short-term exposure to a concentration of a hazardous material. This exposure can vary from a few seconds to as long as one hour. The physical exertion demanded by fire-fighting or other emergency activity can be expected to intensify the effects of any exposure. In addition, the hazard under ambient conditions will likely be exaggerated at elevated temperatures. Health hazards that can result from chronic or repeated long-term exposure to low concentrations of a hazardous material shall not be considered.

2-1.3

The oral route of exposure, i.e., ingestion, is highly unlikely under the conditions anticipated by this standard. If situations are encountered, however, where the oral toxicity values indicate a significantly different health hazard rating than from other, more likely routes of exposure, or where the oral toxicity values would tend to either exaggerate or minimize the hazards likely to be encountered, then professional judgment shall be exercised in assigning the health hazard rating. In such cases, other routes of entry shall be considered to be more appropriate in assessing the hazard. Similarly, inhalation of dusts and mists is unlikely under the conditions anticipated by this standard. In such cases, the health hazard ratings shall also be based on data for the more likely routes of exposure.

2-1.4*

For purposes of assigning the health hazard rating, only the inherent physical and toxic properties of the material shall be considered, unless the combustion or decomposition products present a significantly greater degree of risk.

2-1.5

The degree of hazard shall indicate to fire fighting and emergency response personnel one of the following: that they can work safely only with specialized protective equipment; that they can work safely with suitable respiratory protective equipment; or that they can work safely in the area with ordinary clothing.

2-2 Definitions.

Health Hazard. The likelihood of a material to cause, either directly or indirectly, temporary or permanent injury or incapacitation due to an acute exposure by contact, inhalation, or ingestion.

2-3 Degrees of Hazard.

2-3.1*

The degrees of health hazard shall be ranked according to the probable severity of the effects of exposure to emergency response personnel. For each degree of hazard the criteria are listed in a priority order based upon the likelihood of exposure. Data from all routes of exposure shall be considered when applying professional judgment to assign a health hazard rating.

4 Materials that, under emergency conditions, can be lethal. The following criteria shall be considered when rating materials:

Gases whose LC_{50} for acute inhalation toxicity is less than or equal to 1000 parts per million (ppm);

Any liquid whose saturated vapor concentration at 68°F (20°C) is equal to or greater than ten times its LC_{50} for acute inhalation toxicity, if its LC_{50} is less than or equal to 1000 parts per million (ppm);

Dusts and mists whose LC_{50} for acute inhalation toxicity is less than or equal to 0.5 milligrams per liter (mg/L);

Materials whose LD_{50} for acute dermal toxicity is less than or equal to 40 milligrams per kilogram (mg/kg);

Materials whose LD_{50} for acute oral toxicity is less than or equal to 5 milligrams per kilogram (mg/kg).

3 Materials that, under emergency conditions, can cause serious or permanent injury. The following criteria shall be considered when rating materials:

Gases whose LC_{50} for acute inhalation toxicity is greater than 1000 parts per million (ppm), but less than or equal to 3000 parts per million (ppm);

Any liquid whose saturated vapor concentration at 68°F (20°C) is equal to or greater than its LC_{50} for acute inhalation toxicity, if its LC_{50} is less than or equal to 3000 parts per million (ppm) and that does not meet the criteria for degree of hazard 4;

Dusts and mist whose LC_{50} for acute inhalation toxicity is greater than 0.5 milligrams per liter (mg/L), but less than or equal to 2 milligrams per liter (mg/L);

Materials whose LD_{50} for acute dermal toxicity is greater than 40 milligrams per kilogram (mg/kg), but less than or equal to 200 milligrams per kilogram (mg/kg);

Materials that are corrosive to the respiratory tract;

Materials that are corrosive to the eye or cause irreversible corneal opacity;

Materials that are severely irritating and/or corrosive to skin;

Materials whose LD_{50} for acute oral toxicity is greater than 5 milligrams per kilogram (mg/kg), but less than or equal to 50 milligrams per kilogram (mg/kg).

2 Materials that, under emergency conditions, can cause temporary incapacitation or residual injury. The following criteria shall be considered when rating materials:

Gases whose LC_{50} for acute inhalation toxicity is greater than 3000 parts per million (ppm), but less than or equal to 5000 parts per million (ppm);

Any liquid whose saturated vapor concentration at 68°F (20°C) is equal to or greater than one-fifth ($^1/_5$) its LC_{50} for acute inhalation toxicity, if its LC_{50} is less than or equal to 5000 parts per million (ppm) and that does not meet the criteria for either degree of hazard 3 or degree of hazard 4;

Dusts and mists whose LC_{50} for acute inhalation toxicity is greater than 2 milligrams per liter (mg/L), but less than or equal to 10 milligrams per liter (mg/L);

Materials whose LD_{50} for acute dermal toxicity is greater than 200 milligrams per kilogram (mg/kg), but less than or equal to 1000 milligrams per kilogram (mg/kg);

Materials that are respiratory irritants;

Materials that cause irritating but reversible injury to the eyes;

Materials that are primary skin irritants or sensitizers;

Materials whose LD_{50} for acute oral toxicity is greater than 50 milligrams per kilogram, but less than or equal to 500 milligrams per kilogram (mg/kg).

1 Materials that, under emergency conditions, can cause significant irritation. The following criteria shall be considered when rating materials:

Gases and vapors whose LC_{50} for acute inhalation toxicity is greater than 5000 parts per million (ppm), but less than or equal to 10,000 parts per million (ppm);

Dusts and mists whose LC_{50} for acute inhalation toxicity is greater than 10 milligrams per liter (mg/L), but less than or equal to 200 milligrams per liter (mg/L);

Materials whose LD_{50} for acute dermal toxicity is greater than 1000 milligrams per kilogram (mg/kg), but less than or equal to 2000 milligrams per kilogram (mg/kg);

Materials that are slightly irritating to the respiratory tract, eyes, and skin;

Materials whose LD_{50} for acute oral toxicity is greater than 500 milligrams per kilogram (mg/kg), but less than or equal to 2000 milligrams per kilogram (mg/kg).

0 Materials that, under emergency conditions, would offer no hazard beyond that of ordinary combustible materials. The following criteria shall be considered when rating materials:

Gases and vapors whose LC_{50} for acute inhalation toxicity is greater than 10,000 parts per million (ppm);

Dusts and mists whose LC_{50} for acute inhalation toxicity is greater than 200 milligrams per liter (mg/L);

Materials whose LD_{50} for acute dermal toxicity is greater than 2000 milligrams per kilogram (mg/kg);

Materials whose LD_{50} for acute oral toxicity is greater than 2000 milligrams per kilogram (mg/kg);

Essentially nonirritating to the respiratory tract, eyes, and skin.

Chapter 3 Flammability Hazards

3-1 General.

3-1.1

This chapter shall address the degree of susceptibility of materials to burning. Since many materials will burn under one set of conditions but will not burn under others, the form or condition of the material shall be considered, along with its inherent properties. The definitions for liquid classification are found in NFPA 30, *Flammable and Combustible Liquids Code*.

3-2 Degrees of Hazard.

3-2.1*

The degrees of hazard shall be ranked according to the susceptibility of materials to burning as follows:

4 Materials that will rapidly or completely vaporize at atmospheric pressure and normal ambient temperature or that are readily dispersed in air, and which will burn readily. This includes:

Flammable gases;

Flammable cryogenic materials;

Any liquid or gaseous material that is liquid while under pressure and has a flash point below 73°F (22.8°C) and a boiling point below 100°F (37.8°C) (i.e., Class IA liquids);

Materials that ignite spontaneously when exposed to air.

3 Liquids and solids that can be ignited under almost all ambient temperature conditions. Materials in this degree produce hazardous atmospheres with air under almost all ambient temperatures or, though unaffected by ambient temperatures, are readily ignited under almost all conditions. This includes:

Liquids having a flash point below 73°F (22.8°C) and having a boiling point at or above 100°F (37.8°C) and those liquids having a flash point at or above 73°F (22.8°C) and below 100°F (37.8°C) (i.e., Class IB and Class IC liquids);

Materials that on account of their physical form or environmental conditions can form explosive mixtures with air and that are readily dispersed in air;

Materials that burn with extreme rapidity, usually by reason of self-contained oxygen (e.g., dry nitrocellulose and many organic peroxides).

2 Materials that must be moderately heated or exposed to relatively high ambient temperatures before ignition can occur. Materials in this degree would not under normal conditions form hazardous atmospheres with air, but under high ambient temperatures or under moderate heating might release vapor in sufficient quantities to produce hazardous atmospheres with air. This includes:

Liquids having a flash point at or above 100°F (37.8°C) and below 200°F (93.4°C) (i.e., Class II and Class IIIA liquids);

Solid materials in the form of coarse dusts that burn rapidly but that generally do not form explosive atmospheres with air;

Solid materials in a fibrous or shredded form that burn rapidly and create flash fire hazards, such as cotton, sisal, and hemp;

Solids and semisolids that readily give off flammable vapors.

1 Materials that must be preheated before ignition can occur. Materials in this degree require considerable preheating, under all ambient temperature conditions, before ignition and combustion can occur. This includes:

Materials that will burn in air when exposed to a temperature of 1500°F (815.5°C) for a period of 5 min or less;

Liquids, solids, and semisolids having a flash point at or above 200°F (93.4°C) (i.e., Class IIIB liquids);

Liquids with a flash point greater than 95°F (35°C) that do not sustain combustion when tested using the *Method of Testing for Sustained Combustibility*, per 49 CFR Part 173 Appendix H, or the UN *Recommendations on the Transport of Dangerous Goods*, 8th Revised Edition.

Liquids with a flash point greater than 95°F (35°C) in a water-miscible solution or dispersion with a water noncombustible liquid/solid content of more than 85 percent by weight.

Liquids that have no fire point when tested by ASTM D 92, *Standard Test Method for Flash Point and Fire Point by Cleveland Open Cup*, up to the boiling point of the liquid or up to a temperature at which the sample being tested shows an obvious physical change;

Most ordinary combustible materials.

0 Materials that will not burn. This includes any material that will not burn in air when exposed to a temperature of 1500°F (815.5°C) for a period of 5 min.

Chapter 4 Instability Hazards

4-1 General.

4-1.1

This chapter shall address the degree of susceptibility of materials to release energy. Some materials are capable of rapid release of energy by themselves, through self-reaction or polymerization, or can undergo violent explosive reaction through contact with water or other extinguishing agents or with certain other materials.

4-1.2

The violence of a reaction or decomposition of materials can be increased by heat or pressure, or by mixture with certain other materials to form fuel-oxidizer combinations, or by contact with incompatible substances, sensitizing contaminants, or catalysts.

4-1.3

Because of the wide variations of accidental combinations possible in fire or other emergencies, these extraneous hazard factors (except for the effect of water) cannot be applied to a general numerical rating of hazards. Such extraneous factors must be considered individually in order to establish appropriate safety factors, such as separation or segregation. Such individual consideration is particularly important where significant amounts of materials are to be stored or handled. Guidance for this consideration is provided in NFPA 49, *Hazardous Chemicals Data*.

4-1.4

The degree of instability hazard shall indicate to fire fighting and emergency personnel whether the area shall be evacuated, whether a fire shall be fought from a protected location, whether caution shall be used in approaching a spill or fire to apply extinguishing agents, or whether a fire can be fought using normal procedures.

4-2 Definitions.

4-2.1

For the purposes of this standard, an unstable material is one that can enter into a violent chemical reaction with water. Guidelines for determination of water instability hazard ratings can be found in Appendix D. Reactions with other materials can also result in violent release of energy but are beyond the scope of this standard.

4-2.2

For the purposes of this standard, an unstable material is one that, in the pure state or as commercially produced, will vigorously polymerize, decompose or condense, become self-reactive, or otherwise undergo a violent chemical change under conditions of shock, pressure, or temperature. This calculation is not applicable for the evaluation/classification of organic peroxides. Refer to NFPA 43B, *Code for the Storage of Organic Peroxide Formulations*, for more specific information regarding the instability hazard rating of organic peroxides. Guidelines for determining thermal stability ratings can be found in Appendix D.

4-2.3

Stable materials are those that normally have the capacity to resist changes in their chemical composition, despite exposure to air, water, and heat as encountered in fire emergencies.

4-3 Degrees of Hazard.

4-3.1

The degrees of hazard shall be ranked according to ease, rate, and quantity of energy release as follows:

4 Materials that in themselves are readily capable of detonation or explosive decomposition or explosive reaction at normal temperatures and pressures. This includes materials that are sensitive to localized thermal or mechanical shock at normal temperatures and pressures.

Materials that have an instantaneous power density (product of heat of reaction and reaction rate) at 482°F (250°C) of 1000 W/mL or greater.

3 Materials that in themselves are capable of detonation or explosive decomposition or explosive reaction, but that require a strong initiating source or that must be heated under confinement before initiation. This includes:

Materials that have an instantaneous power density (product of heat of reaction and reaction rate) at 482°F (250°C) at or above 100 W/mL and below 1000 W/mL;

Materials that are sensitive to thermal or mechanical shock at elevated temperatures and pressures;

Materials that react explosively with water without requiring heat or confinement.

2 Materials that readily undergo violent chemical change at elevated temperatures and pressures. This includes:

Materials that have an instantaneous power density (product of heat of reaction and reaction rate) at 482°F (250°C) at or above 10 W/mL and below 100 W/mL;

Materials that react violently with water or form potentially explosive mixtures with water.

1 Materials that in themselves are normally stable, but that can become unstable at elevated temperatures and pressures. This includes:

Materials that have an instantaneous power density (product of heat of reaction and reaction rate) at 482°F (250°C) at or above 0.01 W/mL and below 10 W/mL;

Materials that react vigorously with water, but not violently;

Materials that change or decompose on exposure to air, light, or moisture.

0 Materials that in themselves are normally stable, even under fire conditions. This includes:

Materials that have an instantaneous power density (product of heat of reaction and reaction rate) at 482°F (250°C) below 0.01 W/mL;

Materials that do not react with water;

Materials that do not exhibit an exotherm at temperature less than or equal to 932°F (500°C) when tested by differential scanning calorimetry.

Chapter 5 Special Hazards

5-1 General.

5-1.1

This chapter shall address the other properties of the material that cause special problems or require special fire-fighting techniques.

5-1.2

Special hazards symbols shall be shown in the fourth space of the diagram or immediately above or below the entire symbol.

5-2 Symbols.

5-2.1

Materials that demonstrate unusual reactivity with water shall be identified by the letter W with a horizontal line through the center (~~W~~).

5-2.2

Materials that possess oxidizing properties shall be identified by the letters OX.

Chapter 6 Identification of Materials by Hazard Rating System

6-1

One of the systems delineated in the following illustrations shall be used for the implementation of this standard.

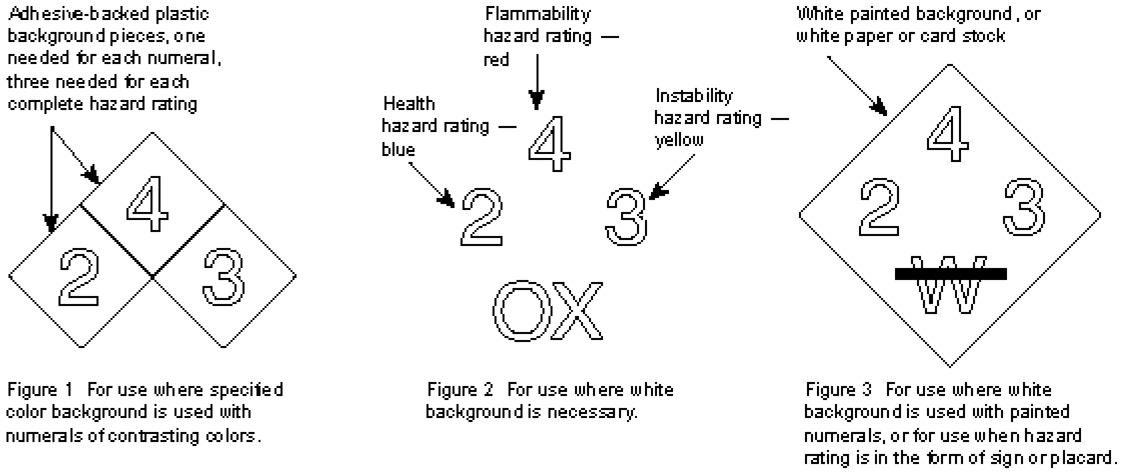
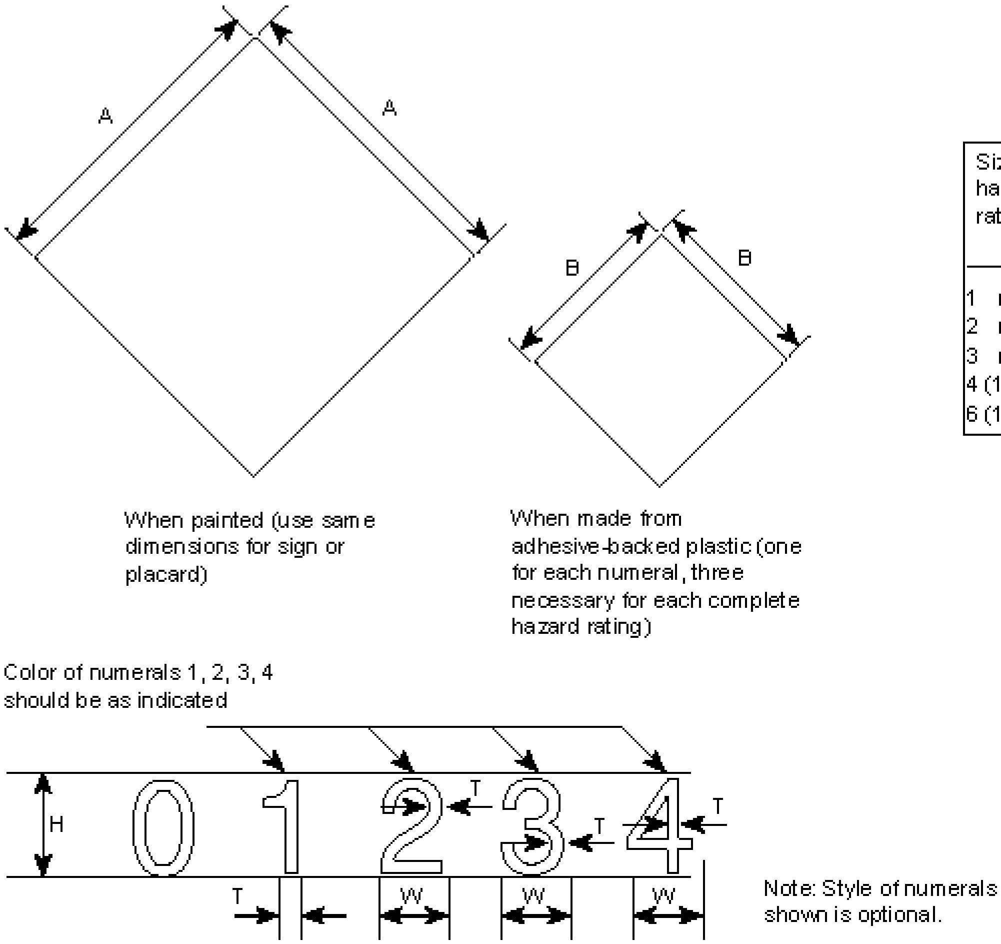


Figure 6-1 Alternate arrangements for display of NFPA 704 Hazard Identification System.



Minimum dimensions of whit
background for hazard rating
(white background is optiona

Size of hazard ratings H	W	T	A
1 (2.54)	0.7 (1.8)	5/32 (0.4)	2 ½ (6.35
2 (5.08)	1.4 (3.6)	5/16 (0.79)	5 (12.7)
3 (7.62)	2.1 (5.3)	15/32 (1.19)	7 ½ (19.05
4 (10.16)	2.8 (7.1)	5/8 (1.59)	10 (25.4)
6 (15.24)	4.2 (10.7)	15/16 (2.38)	15 (38.1)

All dimensions given in inches (cr

Exception: For containers with a capa
one gallon or less, symbols may be r
in size, provided:
1. This reduction is proportionate.
2. The color coding is retained.
3. The vertical and horizontal dimen
the diamond are not less than 1 in. (2
4. The individual numbers are no
smaller than ⅛ in. (0.32 cm) tall.

Figure 6-2 Dimensions of NFPA 704 placard and numerals.

Arrangement and order of hazard ratings—
optional form of application

Distance at which hazard ratings must be legible	Minimum size of hazard ratings required
50 ft (15.24 m)	1 in. (2.54 cm)
75 ft (22.86 m)	2 in. (5.08 cm)
100 ft (30.48 m)	3 in. (7.62 cm)
200 ft (60.96 m)	4 in. (10.16 cm)
300 ft (91.44 m)	6 in. (15.24 cm)

Note: This shows the correct spatial arrangement and order of hazard ratings used for identification of materials by hazard.

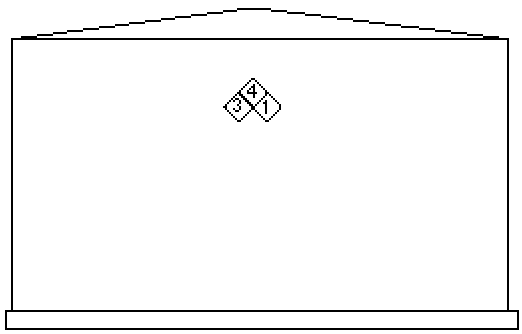


Figure 6-3 Minimum size of numerals for legibility at distance.

Appendix A Explanatory Material

This Appendix is not a part of the requirements of this NFPA document but is included for informational purposes only.

A-1-2.3 The Committee recognizes that the potential exists for certain materials to cause a carcinogenic or teratogenic effect from acute exposure(s). However, there is not sufficient data available to this Committee to allow for the development of numerical ratings based upon carcinogenic or teratogenic potential.

A-2-1.4 Some materials have products of combustion or decomposition that present a significantly greater degree of hazard than the inherent physical and toxic properties of the original material. The degree of hazard is dependent on the conditions at the time of the incident. NFPA 49, *Hazardous Chemicals Data*, provides information on products of combustion when available.

A-2-3.1 Certain materials upon release can cause frostbite. Frostbite, as a health hazard, should be related to the skin/eye component of the health hazard rating criteria.

A-3-2.1 For water-miscible solutions and liquids that do not sustain combustion in accordance with the hazard rating "1" criteria, the individual performing the hazard evaluation should recognize that in large vapor spaces evaporation of volatile components of the mixture can create a flammable mixture in the vapor space which could increase the fire or explosion hazard. This could occur even though the bulk material meets the aforementioned criteria.

Appendix B

Health Hazard Rating

This Appendix is not a part of the requirements of this NFPA document but is included for informational purposes only.

In developing this edition of NFPA 704, the Committee on Classification and Properties of Hazardous Chemicals Data determined that the standard should provide quantitative guidelines for determining the numerical health hazard rating of a material. In addition, the Committee agreed that a "4" or a "3" health hazard rating should be assigned to any material classified as a "Poison-Inhalation Hazard" by the U.S. Department of Transportation (DOT). This classification, "Poison-Inhalation Hazard," was adopted by DOT from the United Nations (UN) criteria detailed in the UN publication, *Recommendations on the Transport of Dangerous Goods*, 4th Edition - Revised, 1986. (See also "Notice of Proposed Rulemaking," Federal Register, Vol. 50, p. 5270 et seq., February 7, 1985, and "Notice of Final Rule," Federal Register, Vol. 50, p. 41092 et seq., October 8, 1985.)

The UN criteria for inhalation toxicity are based upon the LC_{50} and saturated vapor concentration of the material. Furthermore, in addition to inhalation toxicity, the UN has established criteria for oral and dermal toxicity, as well as corrosivity. Based upon these criteria, the UN assigns a given material to categories called Packing Groups I, II, or III. Packing Group I materials represent a severe hazard in transport, Group II materials a serious hazard, and Group III materials a low hazard.

The Committee decided to adopt the UN criteria for toxicity and corrosivity, and correlate Packing Groups I, II, and III with the health hazard ratings "4," "3," and "2," respectively. Adoption of the UN system has several advantages. First, it addresses hazards in transportation, which are similar to the type of emergencies likely to be encountered by fire fighting personnel and emergency responders. Most other hazard ranking systems have been developed for occupational exposures.

Secondly, the UN system is well established, and it is presumed that a large number of chemical manufacturers have already classified (or can easily classify) materials into the appropriate Packing Groups. Finally, users of chemicals can assign "4," "3," or "2" health hazard ratings by establishing whether chemicals have been assigned to UN Packing Groups due to toxicity or corrosivity.

In order to establish "1" and "0" health hazard rankings, the Committee utilized criteria for the "1" and "0" ratings contained in the Hazardous Materials Identification System (HMIS) developed by the National Paint & Coatings Association (NPCA) (*Hazardous Materials Identification System Revised, Implementation Manual*, 1981). Although the NPCA criteria were developed for occupational exposure, the "1" and "0" criteria are on the low end of the hazard spectrum and are fairly consistent with, and complementary to, the "4," "3," and "2" ratings based upon the UN criteria. No UN criteria were established for eye irritation, and the Committee adopted NPCA "3," "2," and "1," and "0" criteria as health hazard ratings for eye irritation.

The Committee made a number of revisions to the proposed hazard rating system to provide conformity with existing industrial practice and to recognize limitations and availability of corrosivity and eye irritation into a single "skin/eye contact" category and utilize descriptive terms for the health hazard ratings. Minor changes were made to the "2," "1," and "0" criteria for oral toxicity and to the "1" and "0" criteria for dermal toxicity. Specifically, the distinction between solids and liquids in the oral toxicity criteria was eliminated, and the cutoff between "1" and "0" rankings for oral and dermal toxicity was lowered from 5000 to 2000 mg/kg.

In summary, the "4," "3," and "2" health hazard rankings for oral, dermal, and inhalation toxicity are based primarily on UN criteria. The "1" and "0" health hazard rankings for oral, dermal, inhalation toxicity, and all of the "skin/eye contact" rankings are based primarily on NPCA criteria.

For the assistance of the user of this standard, the following definitions are quoted from Section 6.5 of *Recommendations on the Transport of Dangerous Goods*, 4th Revised Edition, 1986, published by the United Nations, New York, NY.

"LD_{50} for acute oral toxicity:

That dose of the substance administered which is most likely to cause death within 14 days in one half of both male and female young adult albino rats. The number of animals tested shall be sufficient to give a statistically significant result and be in conformity with good pharmacological practice. The result is expressed in milligrams per kilogram of body weight.

LD_{50} for acute dermal toxicity:

That dose of the substance which, administered by continuous contact for 24 hours with the bare skin of albino rabbits, is most likely to cause death within 14 days in one half of the animals tested. The number of animals tested shall be sufficient to give a statistically significant result and be in conformity with good pharmacological practice. The result is expressed in milligrams per kilogram of body weight.

LC_{50} for acute toxicity on inhalation:

That concentration of vapor, mist or dust which, administered by continuous inhalation to both male and female young adult albino rats for one hour, is most likely to cause death within 14 days in one half of the animals tested. If the substance is administered to the animals as dust or mist, more than 90 percent of the particles available for inhalation in the test must have a diameter of 10 microns or less, provided that it is reasonably foreseeable that such concentrations could be encountered by man during transport. The result is expressed in milligrams per liter of air for dusts and mists or in milliliters per cubic meter of air (parts per million) for vapors."

The following information quoted from Section 6.4 of the above-cited *Recommendations* also applies:

"The criteria for inhalation toxicity of dusts and mists are based on LC_{50} data relating to 1 hour exposures and where such information is available it should be used. However, where only LC_{50} data relating to 4 hour exposures to dusts and mists are available, such figures can be multiplied by four and the product substituted in the above criteria, i.e., LC_{50} (4 hour) × 4 is considered equivalent of LC_{50} (1 hour).

The criteria for inhalation toxicity of vapors are based on LC_{50} data relating to 1 hour exposures, and where such information is available it should be used. However, where only LC_{50} data relating to 4 hour exposures to dusts and mists are available, such figures can be multiplied by two and the product substituted in the above criteria, i.e., LC_{50} (4 hour) × 2 is considered equivalent of LC_{50} (1 hour)."

Appendix C Flammability

This Appendix is not a part of the requirements of this NFPA document but is included for informational purposes only.

The selection of the flash point breaks for the assigning of ratings within the Flammability category has been based upon the recommendations of the Technical Committee on Classification and Properties of Flammable Liquids of the NFPA Committee on Flammable Liquids. This Technical Committee initiated the study that led to the development of this standard. Close cooperation between the Technical Committee and the Committee on Fire Hazards of Materials has continued.

Flash point indicates several things. One, if the liquid has no flash point, it is not a flammable liquid. Two, if the liquid has a flash point, it must be considered flammable or combustible. Three, the flash point is normally an indication of susceptibility to ignition.

The flash point test can give results that would indicate if a liquid is nonflammable or if it should be rated 1 or 2 as a mixture containing, for example, carbon tetrachloride. As a specific example, sufficient carbon tetrachloride can be added to gasoline so that the mixture has no flash point. However, on standing in an open container, the carbon tetrachloride will evaporate more rapidly than the gasoline. Over a period of time, the residual liquid will first show a high flash point, then a progressively lower one until the flash point of the final 10 percent of the original sample will approximate that of the heavier fractions of the gasoline. In order to evaluate the fire hazard of such liquid mixtures, fractional evaporation tests can be conducted at room temperature in open vessels. After evaporation of appropriate fractions, such as 10, 20, 40, 60, and 90 percent of the original sample, flash point tests can be conducted on the residue. The results of such tests indicate the grouping into which the liquid should be placed if the conditions of use are such as to make it likely that appreciable evaporation will take place. For open system conditions, such as in open dip tanks, the open-cup test method will give a more reliable indication of the flammability hazard.

In the interest of reproducible results, it is recommended that:

The flash point of liquids having a viscosity less than 45 SUS (Saybolt Universal Seconds) at 100°F (37.8°C) and a flash point below 200°F (93.4°C) can be determined in accordance with ASTM D 56, *Standard Method of Test for Flash Point by the Tag Closed Tester*. (In those countries that use the Abel or Abel-Pensky closed cup tests as an official standard, these tests will be equally acceptable to the Tag Closed Cup Method.)

The flash point of aviation turbine fuels can be determined in accordance with ASTM D 3828, *Test Method for Flash Point by Setaflash Closed Tester*.

For liquids having flash points in the range of 32°F (0°C) to 230°F (110°C) the determination may be made in accordance with ASTM D 3278, *Flash Point of Liquids by Setaflash Closed*

Tester.

For viscous and solid chemicals the determination may be made in accordance with ASTM E 502, *Flash Point of Chemicals by Closed Cup Methods*.

The flash point of liquids having a viscosity of 45 SUS (Saybolt Universal Seconds) or more at 100°F (37.8°C) or a flash point of 200°F (93.4°C) or higher may be determined in accordance with ASTM D 93, *Test Methods for Flash Point by the Pensky-Martens Closed Tester*.

Appendix D Instability, Thermal Hazard Evaluation Techniques

This Appendix is not a part of the requirements of this NFPA document but is included for informational purposes only.

D-1 Water Reactivity.

Heat of mixing tests between a chemical and water can provide a measure of how vigorous the reaction with water will be in a fire fighting scenario. There are two scenarios to be considered: a material that rapidly releases heat on contact with water, and a material that rapidly releases heat and gas on contact with water. These guidelines apply only to the first scenario, i.e., a chemical that reacts exothermically to release heat on contact with water but does not produce gaseous or low boiling [<212°F (<100°C)] by-products or azeotropes.

INSTABILITY RATING	HEAT OF MIXING	DESCRIPTOR
4		Reactivity with water not considered for rating of 4
3	600 cal/gm or greater	Explosive
2	At or above 100 cal/gm and below 600 cal/gm	Violent
1	At or above 30 cal/gm and below 100 cal/gm	Vigorous
0	Below 30 cal/gm	Nonreactive

The heat of mixing should be determined using a Two Drop Mixing Calorimeter (Hofelich, 1994) or equivalent technique using a 1:1 ratio of chemical to water.

D-2 Thermal Stability.

Thermal stability for hazard evaluation purposes can be done by a number of methods. Frequently used techniques include DTA (Differential Thermal Analysis), DSC (Differential Scanning Calorimetry), and ARC (Accelerating Rate Calorimetry). These tests should be performed in a manner meeting or exceeding the requirements outlined in ASTM E 537, *Standard Test Method for Assessing the Thermal Stability of Chemicals by Methods of Differential Thermal Analysis* (for DTA or DSC) or ASTM E XXX, *Standard Test Method for*

Assessing the Thermal Stability of Chemicals by Methods of Accelerating Rate Calorimetry (in development for ARC).

D-3 Instantaneous Power Density.

Instantaneous power density (IPD) is calculated as the product of the enthalpy of decomposition/reaction and the initial rate of reaction, determined at 482°F (250°C). This quantity represents the amount of heat energy per unit time per unit volume (W/mL) that a material will initially give at 482°F (250°C). The values that make up the power density can be obtained from thermodynamic tables, calculations and experimental measurements. The values are most easily obtained from appropriate measurements using differential scanning calorimetry (ASTM E 698, *Standard Test Method for Arrhenius Kinetic Constants for Thermally Unstable Materials*) or adiabatic runaway calorimetry (Townsend, 1980). In a typical calculation, the rates of reaction as a function of temperature are obtained and expressed in terms of an Arrhenius expression and an overall, initial-rate expression (Laidler, 1965). This rate expression represents the initial rate of decomposition where the decrease in concentration of the material as a result of the decomposition/reaction has not progressed to a significant (< 5%) level. This allows one to use the initial concentration of the material in the simplified rate expression. (*See Appendix E for the references*.)

INSTABILITY RATING	INSTANTANEOUS POWER DENSITY AT 250°C
4	1000 W/mL or greater
3	At or above 100 W/mL and below 1000 W/mL
2	At or above 10 W/mL and below 100 W/mL
1	At or above 0.01 W/mL and below 10 W/mL
0	Below 0.01 W/mL

In order to clarify the calculation of instantaneous power density, a sample calculation is provided.

Differential scanning calorimetry was carried out and the following parameters were obtained for a material of interest:

Enthalpy of decomposition (ΔH): -80.5 cal/g

Arrhenius Activation Energy (E_a): 36.4 kcal/mol

Arrhenius Pre-exponential (^{A}PRE): $1.60 \times 10^{+15}\ s^{-1}$

Reaction Order (n) 1

Initial concentration of material, or density of pure material (Conc.): 0.80 g/mL

The initial rate of decomposition of the material at 482°F (250°C) can be calculated using the following Arrhenius expression, where R is the universal gas whose value is taken as 1.987 cal/(mol°C):

$$\text{Rate} = \text{Conc}^{\text{Order}} \times A_{\text{PRE}} \times e^{-E_a/RT}$$

UNITS:

$$\frac{g}{mL \times s} = \left(\frac{g}{mL}\right)^{\text{Order}} \times \left(\frac{g}{mL \times s}\right)^{1-\text{Order}} \times e^{-\frac{cal/mol}{cal/(mol\,x\,K)\,K}}$$

$$\text{Rate} = 0.80^{+1} \times 1.60 \times 10^{+15} \times e^{-\frac{36400}{1.987 \times (273 + 250)}}$$

$$\text{Rate} = 0.79\,\frac{g}{mL \times s}$$

$$\text{Rate} = 0.80^{+1} \times 1.60 \times 10^{+15} \times e^{-\frac{36400}{1039}}$$

The power density is given as the product of this decomposition and the enthalpy of decomposition (the value of 4.184 W/cal/s allows the use of units W/mL):

$$\text{IPD} = -\Delta H \times \text{Rate}$$

$$\text{UNITS}: \frac{W}{mL} = \frac{cal}{g} \times \frac{g}{mL \times s} \times 4.184\,\frac{W}{cal/s}$$

$$\text{IPD} = -(-80.5) \times 0.79 \times 4.184\,\frac{W}{cal/s}$$

$$\text{IPD} = 63\,\frac{cal}{s \times mL} \times 4.184\,\frac{W}{cal/s}$$

$$\text{IPD} = 270\,\frac{W}{mL}$$

The instantaneous power density (IPD) is used as a positive value: the greater the power density, the greater the rate of energy release per volume. Therefore, the exothermic enthalpy of reaction, thermodynamically taken with a negative sign to show release of heat to the surroundings, is taken as a negative so as to rectify the sign of IPD.

This material, having an IPD = 270 W/mL, would be rated a 3 per the table.

Appendix E Referenced Publications

E-1 The following documents or portions thereof are referenced within this standard for informational purposes only and thus are not considered part of the requirements of this document. The edition indicated for each reference is the current edition as of the date of the NFPA issuance of this document.

E-1.1 NFPA Publications. National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.

NFPA 30, *Flammable and Combustible Liquids Code*, 1996 edition.

NFPA 43B, *Code for the Storage of Organic Peroxide Formulations*, 1993 edition.

NFPA 49, *Hazardous Chemicals Data*, 1994 edition.

NFPA 325, *Guide to Fire Hazard Properties of Flammable Liquids, Gases, and Volatile Solids*, 1994 edition.

NFPA 495, *Explosive Materials Code*, 1996 edition.

E-1.2 ASTM Publications. American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103.

ASTM D 56, *Standard Method for Test for Flash Point by the Tag Closed Tester*, 1993.

ASTM D 92, *Standard Test Method for Flash Point and Fire Point by Cleveland Open Cup*, 1990.

ASTM D 93, *Test Methods for Flash Point by the Pensky-Martens Closed Tester*, 1994.

ASTM D 3828, *Test Method for Flash Point by Setaflash Closed Tester*, 1993.

ASTM D 3278, *Flash Point of Liquids by Setaflash Closed Tester*, 1989.

ASTM E 472, *Practice for Reporting Thermoanalytical Data*, 1986.

ASTM E 502, *Flash Point of Chemicals by Closed Cup Methods*, 1984.

ASTM E 537, *Standard Test Method for Assessing the Thermal Stability of Chemicals by Methods of Differential Thermal Analysis*, 1986.

ASTM E 698, *Standard Test Method for Arrhenius Kinetic Constants for Thermally Unstable Materials*, 1979.

ASTM E 967, *Practice for Temperature Calibration of Differential Scanning Calorimeters and Differential Thermal Analyzers*, 1992.

ASTM E XXX, *Standard Test Method for Assessing the Thermal Stability of Chemicals by Methods of Accelerating Rate Calorimetry* (in development).

E-1.3 Other Publications.

Federal Register, "Notice of Final Rule," Vol. 50, p. 41092 et seq., October 8, 1985.

Federal Register, "Notice of Proposed Rulemaking," Vol. 50, p. 5270 et seq., February 7, 1985.

Frurip, D. J., T. C. Hofelich, A. N. Syverud, and L. F. Whiting, "Some Simple Rules-of-Thumb for DSC Data Interpretation," 1991 NATAS Proceedings, 1991.

Hofelich, T. C., D. J. Frurip, and J. B. Powers, "The Determination of Compatibility via Thermal Analysis and Mathematical Modeling," *Process Safety Progress*, Vol. 13, No 4. pp. 227-233, 1994.

Hofelich, T. C. and R. C. Thomas, "The Use/Misuses of the 100 Degree Rule in the Interpretation of Thermal Hazard Tests," CCPS International Symposium on Runaway Reactions, New York, pp. 74-85, March 7, 1989.

Laidler, K. L., *Chemical Kinetics*, Chapter 3, McGraw Hill, New York, 1965.

National Paint & Coatings Association, *Hazardous Materials Identification System Revised, Implementation Manual*, 1981.

Tou, J. C. and L. F. Whiting, “A Cradle-Glass Ampoule Sample Container for Differential Scanning Calorimetric Analysis,” *Thermochimica Acta*, Vol. 42, Elsevier Scientific Publishing Co., Amsterdam, 1980.

Townsend, D. J. and J. C. Tou, "Thermal Hazard Evaluation by an Accelerating Rate Calorimeter," *Thermochimica Acta*, Vol. 37, pp. 1-30, Elsevier Scientific Scientific Publishing Co., Amsterdam, 1980.

Whiting, L. F., M. S. LaBean, and S. S. Eadie, “Evaluation of a Capillary Tube Sample Container for Differential Scanning Calorimetry,” *Thermochimica Acta*, Vol. 136, Elsevier Scientific Publishing Co., Amsterdam, 1988.

E-1-3.1 Additional Publications/U.S. Government Regulations.

Code of Federal Regulations, Title 49, Part 173, "Method of Testing for Sustained Combustibility."

United Nations (UN), *Recommendations on the Transport of Dangerous Goods*, 4th Revised Edition, United Nations, New York, 1986.

United Nations (UN), *Recommendations on the Transport of Dangerous Goods*, 8th Revised Edition, United Nations, New York, 1986.

NFPA 705

1993 Edition

Recommended Practice for a Field Flame Test for Textiles and

1993 Edition

This edition of NFPA 705, *Recommended Practice for a Field Flame Test for Textiles and Films*, was prepared by the Technical Committee on Fire Tests and acted on by the National Fire Protection Association, Inc. at its Fall Meeting held November 16-18, 1992, in Dallas, TX. It was issued by the Standards Council on January 15, 1993, with an effective date of February 12, 1993, and supersedes all previous editions.

The 1993 edition of this document has been approved by the American National Standards Institute.

Origin and Development of NFPA 705

The new NFPA 705 is a complete revision of NFPA 701, Chapter 10, Field Test: Match Flame Test. Due to the lack of data demonstrating a relationship between the field match test and NFPA 701, small- or large-scale testing, the committee determined it would be appropriate to create this document so as not to perpetuate any application of a correlation. The field match test does not incorporate the more rigorous laboratory testing methods incorporated into the small- and large-scale testing such as conditioning of specimen, reproducibility, and repeatability. The revisions to NFPA 705 incorporate an increase in safety precautions during the testing procedure, type of ignition source, and removal of sample prior to testing.

Technical Committee on Fire Tests

Alfred J. Hogan, Reedy Creek Improvement District, FL
Rep. Fire Marshals Assoc. of N. America

Wayne D. Holmes, Professional Loss Control, Inc., PA

Marc L. Janssens, Nat'l Forest Products Assn. DC

Donald C. Knodel, E I du Pont de Nemours & Co., DE
Rep. American Fiber Mfr. Assn.

James R. Lawson, NIST/Center for Fire Research, MD

Gerald E. Lingenfelter, American Ins. Services Group Inc., NY

George E. Meyer, Warnock Hersey Int'l Inc., CA

John W. Michener, Milliken Research Corp., SC
Rep. American Textile Mfr. Inst., Inc.

James A. Milke, University of Maryland, MD

James C. Norris, Union Carbide, PA

Leon Przybyla, Underwriters Laboratories Inc., IL

Sivon C. Reznikoff, Arizona State University, AZ

Herman Stone, General Foam, PA

T. Hugh Talley, Hugh Talley Co., TN
Rep. Upholstered Furniture Action Council

Richard P. Thornberry, The Code Consortium, Inc., CA

Robert J. Wills, American Iron & Steel Inst., AL

Peter J. Gore Willse, Industrial Risk Insurers, CT

Alternates

Robert M. Berhinig, Underwriters Laboratories Inc., IL
(Alt. to L. Przybyla)

Peter H. Billing, Nat'l Forest Products Assn., IL
(Alt. to M. L. Janssens)

Delbert Boring, American Iron & Steel Inst., DC

(Alt. to R. J. Wills)

Philip J. DiNenno, Hughes Assoc., Inc., MD
(Alt. to J. J. Beitel)

Richard D. Gottwald, Society of the Plastics Industry, DC
(Alt. to J. A. Blair)

Carl A. Hafer, Southwest Research Inst., TX
(Alt. to SRI Rep.)

R. Joseph Pearson, Warnock Hersey Int'l Inc., NY
(Alt. to G. E. Meyer)

Hardy Poole, American Textile Mfr. Inst., DC
(Alt. to J. W. Michener)

John Roberts, Underwriters Laboratories of Canada, Ontario
(Alt. to P. Higginson)

William A. Thornberg, Industrial Risk Insurers, IL
(Alt. to P. J. G. Willse)

Dee H. Wong, Professional Loss Control Inc., TN
(Alt. to W. D. Holmes)

Joe Ziolkowski, American Furniture Mfr. Assoc., NC
(Alt. to T. H. Talley)

Nonvoting

A. J. Bartosic, Rohm & Haas Co., PA

Herman H. Spaeth, Novato, CA
(Member Emeritus)

Walter P. Sterling, NFPA Staff Liaison

This list represents the membership at the time the Committee was balloted on the text of this edition. Since that time, changes in the membership may have occurred.

NOTE: Membership on a Committee shall not in and of itself constitute an endorsement of the Association or any document developed by the Committee on which the member serves.

Committee Scope: To develop standards for fire testing procedures when such standards are not available; review existing fire test standards and recommend appropriate action to NFPA; recommend the application of and advise on the interpretation of acceptable test standards for fire problems of concern to NFPA technical committees and members; act in a liaison capacity between NFPA and the committees of other organizations writing fire test standards. The

Committee is not responsible for fire tests that are used to evaluate extinguishing agents, devices or systems.

NFPA 705
Recommended Practice for a Field Flame Test for Textiles and Films

1993 Edition

NOTICE: An asterisk (*) following the number or letter designating a paragraph indicates explanatory material on that paragraph in Appendix A.
Information on referenced publications can be found in Chapter 5.

Chapter 1 Introduction

1-1 Scope.

1-1.1

This recommended practice provides guidance to enforcement officials for the field application of an open flame to textiles and films (1) that have been in use in the field or (2) for which reliable laboratory data are not available.

1-1.2

There is no known correlation between this recommended practice and NFPA 701, *Standard Methods of Fire Tests for Flame-Resistant Textiles and Films*, or full-scale fire behavior.

1-1.3

These recommendations apply to materials used in the interior of buildings, for protective outdoor coverings, such as tarpaulins and tents, and plastic films (with or without reinforcing or backing) used for decorative or other purposes inside buildings or as temporary or permanent enclosures for buildings under construction.

1-1.4

Materials applied to surfaces of buildings or backing materials as interior finishes in buildings should be tested and classified in accordance with NFPA 255, *Standard Method of Test of Surface Burning Characteristics of Building Materials*.

1-2 Purpose.

The purpose of this recommended practice is to provide authorities having jurisdiction with a field means of determining the tendency of textiles and films to sustain burning subsequent to the application of a relatively small, open flame. The methods described herein and the results do not correlate with any known test method; and factors relating to reproducibility and correlation have not been determined; therefore, they should not be relied upon when more definitive test data are available.

1-3 Definitions.

Film. A flat section of a thermoplastic resin, a regenerated cellulose derivative, or other material that is extremely thin in comparison to its length and breadth and has a nominal maximum thickness of 0.01 in. (0.25 mm).

Kitchen Match. A piece of wood with a combustible mixture at its tip that bursts into flame through friction, with an approximate length of $2^{7}/_{16}$ in. (61.9 mm) and an approximate weight of 1 oz (29 g) per hundred.

Textile. A material made of natural or man-made fibers and used for the manufacture of items such as curtains, clothing, and furniture fittings.

Chapter 2 General

2-1 Application/Specific Limitations.

2-1.1*

The field test method may be useful to regulatory officials as an indicator of whether a material being used or installed burns very easily or may be flame resistant as indicated by (a) cessation of burning when the igniting flame is removed, (b) failure to burn at all, or (c) continuing to burn nonaggressively after the igniting flame is removed. The field test method has utility only when the authority having jurisdiction has no reliable data and, therefore, is forced to rely solely on the field test findings.

2-1.2

There are only two types of materials for which the field test method can be deemed to provide foolproof and totally adequate results: those made entirely of noncombustible inorganic material and those that ignite and burn readily on exposure to a small flame. For example, with only limited experience, an inspector will have no difficulty in identifying an all-mineral fiber fabric by employing a small, open flame, and no other procedure is necessary. The only effect of a small fire exposure on a mineral fiber fabric is to burn off the surface coloring, if any, leaving the threads themselves virtually undamaged. This result is not obtained with any other type of decorative fabric and, therefore, is readily recognized. At the other extreme, if a material ignites and burns readily from the application of a small, open flame from a source such as a kitchen match, showing no semblance of flame resistance, no other procedure is necessary, since the material obviously is not acceptable.

2-1.3

Between these two extremes, the field test method has a limited and a varying degree of reliability. Within this large group, comprising the great majority of materials the enforcement official is likely to encounter in the field, the most reliable results are obtained in the testing of cellulose-based materials (cotton, rayon, and paper) flame-retardant treated with the common inorganic salt formulations. These materials retain their shape reasonably during testing, and the results are not greatly affected by differences in sample size or severity of fire exposure. However, the least reliable results are obtained with chemically treated fabrics of synthetic fibers or flexible plastic films and laminates. These materials are subject to a variety of physical changes when exposed to fire, such as shrinking, curling, melting, elongating, and similar distortions, making the examination of small samples quite difficult and the results ambiguous. Furthermore, some of these thermoplastic materials are apt to appear flame resistant with small flame exposures but ignite and burn fiercely with longer exposures to larger ignition sources.

Chapter 3 Procedure

3-1* Materials.

3-1.1

Specimens should be samples removed from the existing material.

3-1.2

Specimens should be dry and should be a minimum of $^{1}/_{2}$ in. × 4 in. (12.7 mm × 101.6 mm).

3-2 Open Flame.

The fire exposure should be from a common wood kitchen match or source with equivalent flame properties and should be applied for 12 seconds.

3-3* Method.

3-3.1

The test should be performed in a draft-free and safe location free of other combustibles.

3-3.2

The sample should be suspended (preferably by means of a spring clip, tongs, or similar device) with the long axis vertical, the flame supplied to the center of the bottom edge, and the bottom edge $^{1}/_{2}$ in. (12.7 mm) above the bottom of the flame.

3-3.3

After 12 seconds of exposure, the match is to be removed gently away from the sample.

3-4 Requirements.

During the exposure, flaming should not spread over the complete length of the sample or in excess of 4 in. (101.6 mm) from the bottom of the sample (for larger size samples). There should be not more than two seconds of afterflame. Materials that break or drip flaming particles should be rejected if the materials continue to burn after they reach the floor.

Chapter 4 Summary

4-1 Limitations.

The deficiencies and limitations of the field test method can lead to misleading or erroneous results, and the error can be in both directions. It is quite possible to have a too-small sample show several seconds of afterflaming, causing the material to be rejected. It is equally possible for improper or inadequate field procedures to indicate satisfactory flame resistance. This can result in dangerous errors.

4-2 Precautions.

Field procedures are useful, but they must be used with good judgment and their limitations recognized. Field tests should not be relied on as the sole means for ensuring adequate flame resistance of decorative materials but are useful in augmenting a comprehensive regulatory program.

Chapter 5 Referenced Publications

5-1

The following documents or portions thereof are referenced within this recommended practice and should be considered part of the recommendations of this document. The edition indicated for each reference is the current edition as of the date of the NFPA issuance of this document.

5-1.1 NFPA Publications.

National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.

NFPA 255, *Standard Method of Test of Surface Burning Characteristics of Building Materials*, 1990 edition

NFPA 701, *Standard Methods of Fire Tests for Flame-Resistant Textiles and Films*, 1989 edition

Appendix A

This Appendix is not a part of the requirements of this NFPA document, but is included for information purposes only.

A-2-1.1

By far, the greatest benefit can be derived from the field test method when the inspector has had the opportunity to practice and experiment on a variety of decorative materials and particularly to make comparisons between the results of laboratory tests performed in accordance with NFPA 701, *Standard Methods of Fire Tests for Flame-Resistant Textiles and Films*, and the less precise field test method. Experience is the best teacher, and it is strongly recommended that inspectors who may be involved in this activity familiarize themselves with a wide variety of treated and inherently flame-resistant fabrics of many types and their typical behavior under a variety of test conditions. With this background, the inspector possesses a greater capability for properly interpreting field test results.

A-3-1

A difficult and controversial question concerns the minimum number of specimens that should be tested. The answer can be dictated by a number of factors. A good general rule is the more specimens, the better; but, in all cases, the inspector should exercise good judgment. The variety of circumstances that can be encountered can be illustrated by some specific examples:

(a) A dance in a school gymnasium, decorated by students with a profusion of paper banners, crepe paper streamers, figures made of pieces of tissue paper stuffed in chicken wire molds, hay and straw, painted fabrics, dry palm fronds, and similar products, all alleged to be flame resistant: In this situation, the inspector has neither reason nor excuse to be inhibited in taking samples for tests. The materials are inexpensive, are likely not intended to be reused, and taking samples for tests will cause little if any change to the decorative effect.

(b) A large assembly tent made of supposedly treated canvas but with no identifying marks and no confirming evidence of such treatment: The life hazard is acute, tent canvas can readily be patched, and, therefore, the situation warrents nothing less than sufficient samples from all sections of canvas for the inspector to be satisfied that the quality and uniformity of the treatment are acceptable.

(c) A nightclub with very expensive draperies known to be adequately flame-retardant treated when installed two years previously: The only way to be certain that the quality of flame resistance remains acceptable is to take a sample, but in the interest of maintaining good public relations, the inspector should be diplomatic and persuasive. Usually, a place can be found where a small but adequate sample can be extracted without causing any visible damage. Often this is the most the inspector can expect to get.

A-3-3

There can be complications of a technical nature. Decorative fabrics sometimes are installed overhead, in or near a horizontal position. Some plastic films or fabrics woven of thermoplastic synthetic fibers will successfully resist continued burning in the normal vertical position of test, but will exhibit continued burning if exposed in a horizontal position. Fabrics or films installed horizontally may be a serious threat to safety in a fire situation, and, therefore, the inspector is justified in testing the material in a horizontal position.

A somewhat similar problem can exist with some of the new and increasingly popular decorative fabrics with one or more types of fibers in the threads along the length (warp) and different fibers in the threads along the widths (fill). This can result in a different burning behavior in the two directions of the fabric to the extent that, where a flame-retardant treatment has been applied, tests for flame resistance in one direction may be acceptable, but the fabric could show continued burning in the other direction. Where visual examination of the fabric indicates this condition might exist, the inspector should test samples cut with the long dimension paralleling both the length and width of the fabric.

NFPA 750

1996 Edition

Standard on Water Mist Fire Protection Systems

1996 Edition

This edition of NFPA 750, *Standard on Water Mist Protection Systems,* was prepared by the

Technical Committee on Water Mist Fire Suppression Systems and acted on by the National Fire Protection Association, Inc., at its Annual Meeting held May 20-23, 1996, in Boston, MA. It was issued by the Standards Council on July 18, 1996, with an effective date of August 9, 1996.

This edition of NFPA 750 was approved as an American National Standard on July 26, 1996.

Origin and Development of NFPA 750

In 1993, representatives from the research and engineering communities, water mist system manufacturers, the insurance industry, enforcement authorities, and industrial users met and organized the NFPA Technical Committee on Water Mist Fire Suppression Systems. The committee started work on developing a new NFPA document that would begin to standardize water mist technology and provide for reliable design and installation of these systems.

Water mist systems were introduced in the 1940s and were utilized for specific applications such as on passenger ferries. The renewed interest in water systems is due partially to the phasing out of Halon and their potential as a fire safety system for spaces where the amount of water that can be stored or that can be discharged is limited. In addition, their application and effectiveness for residential occupancies, flammable liquids storage facilities, and electrical equipment spaces continues to be investigated with encouraging results.

NFPA 750 will contain elements which are similar to other types of fire protection systems such as automatic sprinklers, fixed water spray, carbon dioxide, and Halon. In many ways, water mist can be thought of as a hybrid of these systems. Overall, water mist systems utilize water as the extinguishing, suppression, or control medium, but do so in a nontraditional manner. In developing this new standard, the committee addressed system components and hardware, system types, installation requirements, design objectives, hazard classifications, calculations, water supplies, atomizing media, plans, documentation, acceptance criteria, and maintenance considerations.

Technical Committee on
Water Mist Fire Suppression Systems

Jon S. Casler, Fike Protection Systems, MO

Marvin Charney, Kidde-Fenwal, Inc., CA
Rep. Fire Suppression Systems Assn.

Salvatore A. Chines, Industrial Risk Insurers, CT

Robert L. Darwin, U.S. Dept. of the Navy, DC

Jack W. Davis, Sprinkler Fitters Local 483 JAC, CA
Rep. United Assn. of Journeymen/Apprentices of Plumbing/Pipe Fitting

John F. Devlin, Schirmer Engr, Corp., VA

William J. Fries, Liberty Mutual Insurance Co., MA
Rep. The Alliance of American Insurers

William A. Froh, U.S. Dept. of Energy, MD

Victor Gameiro, Marioff Hi-fog Oy, Canada

John A. Gioseffi, Broward Fire Equip & Serv Inc., FL
Rep. Nat'l Assn. of Fire Equipment Distributors Inc

Matthew T. Gustafson, U.S. Coast Guard, DC

Raymond N. Hansen, U.S. Air Force, Civil Engr Support Agency, FL

Thomas W. Jaeger, Gage Babcock & Assoc., Inc., VA

Andrew Kim, Nat'l Research Council of Canada, Ontario, Canada

Michael Kincaid, Securiplex, Inc., PQ, Canada

George E. Laverick, Underwriters Laboratories Inc., IL

Daniel Madrzykowski, U.S. Nat'l Inst. of Standards & Technology, MD

M. L. "Larry" Maruskin, U.S. Fire Administration, MD

Jerome S. Pepi, Grinnell Corp., RI
Rep. Nat'l Fire Sprinkler Assn.

Lyle R. "Skip" Perkins, Florida Power Corp., FL
Rep. Electric Light Power Group/Edison Electric Inst.

John F. Scarff, Marriott Corp., DC

Michael B. Stevens, NASA Kennedy Space Center, FL

Thomas F. Ziegler, GTE Service Corp., CT

Alternates

James G. Bisker, U.S. Dept. of Energy, MD
(Alt. to W. A. Froh)

William M. Carey, Underwriters Laboratories Inc., IL
(Alt. to G. E. Laverick)

Francois Demers, Securiplex, Inc., PQ, Canada
(Alt. to M. Kincaid)

Philip J. DiNenno, Hughes Assoc., Inc., MD
(Alt. to J. R. Mawhinney)

Paul H. Dobson, Factory Mutual Research Corp., MA
(Alt. to R. G. Bill)

Russell P. Fleming, Nat'l Fire Sprinkler Assn., NY
(Alt. to J. S. Pepi)

Thomas J. Forsythe, Gage Babcock & Assoc., CA
(Alt. to T. W. Jaeger)

Morgan J. Hurley, U.S. Coast Guard, DC
(Alt. to M. T. Gustafson)

Anton K. N. Jensen, Jr., Liberty Mutual Insurance, Co., IL
(Alt. to W. J. Fries)

David H. Kay, U.S. Dept. of the Navy, DC
(Alt. to R. L. Darwin)

George A. Krabbe, Automatic Suppression Systems, Inc., IL
(Alt. to M. Charney)

Jane I. Lataille, Industrial Risk Insurers, CT
(Alt. to S. A. Chines)

Earl D. Neargarth, Fike Protection Systems, MO
(Alt. to J. S. Casler)

Erin A. M. Oneisom, U.S. Air Force, Civil Engr Support Agency, FL

(Alt. to R. N. Hansen)

Martin H. Reiss, Rolf Jensen & Assoc., Inc., MA
(Alt. to C. L. Vollman)

John A. Sileo, Johnson & Higgins, CT
(Alt. to R. Anderson)

Goran Sundholm, Marioff Hi-fog Oy, Finland
(Alt. to V. Gameiro)

Phillip Tapper, NASA, DC
(Alt. to M. B. Stevens)

Jiann C. Yang, U.S. Nat'l Inst. of Standards & Technology, MD
(Alt. to D. Madrzykowski)

Nonvoting

James R. Butz, ADA Technologies, Inc., CO

Stephen G. Leeds, Lawrence Livermore Nat'l Laboratory, CA
Rep. T/C on Electronic Computer Systems

Douglas J. Pickersgill, Fire and Safety Systems, QU, Australia

Fernando Vigara, Vimpex - Security Devices, SA, Spain

Milosh T. Puchovsky/Robert E. Solomon, NFPA Staff Liaisons

This list represents the membership at the time the Committee was balloted on the text of this edition. Since that time, changes in the membership may have occurred.

NOTE: Membership on a Committee shall not in and of itself constitute an endorsement of the Association or any document developed by the Committee on which the member serves.

Committee Scope: This Committee shall have primary responsibility for documents on the design, installation, and maintenance of systems which use a water mist for the control, suppression, or extinguishment of fire.

NFPA 750
Standard on
Water Mist Fire Protection Systems

1996 Edition

NOTICE: An asterisk (*) following the number or letter designating a paragraph indicates explanatory material on that paragraph in Appendix A.
Information on referenced publications can be found in Chapter 12 and Appendix C.

Chapter 1 General Information

1-1* Scope.

This standard contains the minimum requirements for the design, installation, maintenance, and testing of water mist fire protection systems. This standard does not provide definitive fire performance criteria nor does it offer specific guidance on how to design a system to control, suppress, or extinguish a fire. Reliance is placed on the procurement and installation of listed water mist equipment or systems which have demonstrated performance in fire tests as part of a listing process.

1-2 Purpose.

The purpose of this standard is to provide a reasonable degree of protection for life and property from fire through the standardization of design, installation, maintenance, and testing requirements for water-based fire suppression systems that use a specific spray (mist) that absorbs heat, displaces oxygen, or blocks radiant heat to control, suppress, or extinguish fires as required by the application. This standard endeavors to establish minimum requirements for water mist technology based on sound engineering principles, test data, and field experience. Nothing in this standard is intended to restrict new technologies or alternate arrangements, provided the level of safety prescribed by this standard is not lowered. Materials or devices not specifically designated by this standard shall be utilized in accordance with all conditions, requirements, and limitations of their listings.

NOTE 1: Water mist systems are specialized fire protection systems. Design and installation of these systems necessitates specialized training, knowledge, and experience.

NOTE 2: Water mist systems offer potential benefits for many specialized applications, particularly where available water supplies are limited or where the application of water needs to be restricted. Potential benefits also might exist for applications previously protected by gaseous and other fire suppressant agents.

1-3 Retroactivity Clause.

The provisions of this document are considered necessary to provide a reasonable level of protection from loss of life and property from fire. They reflect situations and the state of the art at the time the standard was issued.

Unless otherwise noted, it is not intended that the provisions of this document be applied to facilities, equipment, structures, or installations that were existing or approved for construction or installation prior to the effective date of this document.

Exception: In those cases where it is determined by the authority having jurisdiction that the existing situation involves a distinct hazard to life or property, this standard shall apply.

1-4 Definitions and Units.

1-4.1 Definitions.

Approved.* Acceptable to the authority having jurisdiction.

Atomizing Media. Compressed air or other gases that produce water mist by mechanical mixing with water.

Authority Having Jurisdiction.* The organization, office, or individual responsible for approving equipment, an installation, or a procedure.

Deluge System. A water mist system using open nozzles attached to a piping system which is connected to a water supply through a valve that is opened by means of a detection system installed in the same area as the mist nozzles. When the valve opens, water flows into the piping system and discharges through all nozzles attached to the system.

Dry Pipe System. A water mist system using automatic nozzles attached to a piping system containing air, nitrogen, or inert gas under pressure, the release of which (as from an opening of an automatic nozzle) allows the water pressure to open a dry pipe valve. The water then flows into the piping system and out through any open nozzles.

Dv_f. A drop diameter such that the cumulative volume, from zero diameter to this respective diameter, is the fraction, f, of the corresponding sum of the total distribution.

NOTE: $Dv_{0.50}$ is the volume median diameter; that is, 50 percent of the total volume of liquid is in drops of smaller diameter and 50 percent is in drops of larger diameter.

Enclosure. The case, housing, partition, or walls that will substantially contain water mist in the vicinity of the hazard for a sufficient length of time to achieve the fire protection objectives.

Engineered Systems. Those systems that need individual calculation and design to determine the flow rates, nozzle pressures, pipe size, area, or volume protected by each nozzle, discharge density of water mist, the number and types of nozzles, and the nozzle placement in a specific system.

Fire Control. The limitation of the growth of a fire by prewetting adjacent combustibles and controlling ceiling gas temperatures to prevent structural damage.

Fire Extinguishment. The complete suppression of a fire until there are no burning combustibles.

Fire Suppression. The sharp reduction of the rate of heat release of a fire and the prevention of regrowth.

High Pressure System. A water mist system where the distribution system piping is exposed to pressures of 500 psi (34.5 bars) or greater.

Intermediate Pressure System. A water mist system where the distribution system piping is exposed to pressures greater than 175 psi (12.1 bars) but less than 500 psi (34.5 bars).

Listed.* Equipment, materials, or services included in a list published by an organization acceptable to the authority having jurisdiction and concerned with evaluation of products or services that maintains periodic inspection of production of listed equipment or materials or periodic evaluation of services and whose listing states either that the equipment, material, or service meets identified standards or has been tested and found suitable for a specified purpose.

Local Application System. A water mist system arranged to discharge directly on an object or hazard in an enclosed, unenclosed, or open outdoor condition.

Low Pressure System. A water mist system where the distribution piping is exposed to pressures of 175 psi (12.1 bars) or less.

Preaction System. A water mist system using automatic nozzles attached to a piping system containing air that might or might not be under pressure, with a supplemental detection system installed in the same areas as the mist nozzles. The actuation of the detection system opens a valve that allows water to flow into the piping system and discharges through all opened nozzles in the system.

Pre-engineered Systems. Those systems having predetermined flow rates, nozzle pressures, and volumes and spray flux densities of water mist. These systems have the specific pipe size, maximum and minimum pipe lengths, flexible hose specifications, number of fittings, and number and types of nozzles prescribed by a testing laboratory. Systems are provided with either a self-contained or external water supply. Based on actual test fires, the hazards protected by these systems are specifically limited as to type and size by a testing laboratory. Limitations on hazards that are allowed to be protected by these systems are contained in the manufacturer's installation manual, which is referenced as part of the listing.

Shall. Indicates a mandatory requirement.

Should. Indicates a recommendation or that which is advised but not required.

Single Fluid System. A water mist system utilizing a single piping system to supply each nozzle.

Standard. A document, the main text of which contains only mandatory provisions using the word "shall" to indicate requirements, which is in a form generally suitable for mandatory reference by another standard or code or for adoption into law. Nonmandatory provisions shall be located in an Appendix, footnote, or fine-print note and are not to be considered a part of the requirements of a standard.

Total Compartment Application System. A system designed to discharge water mist to protect all hazards in an enclosure.

Twin Fluid System. A water mist system in which water and atomizing media are separately supplied to and mixed at the water mist nozzle.

Valves.

Automatic (Activation) Valve. The valve controlling water flow into the mist system, including the alarm, dry pipe, deluge, zone, and group valves.

Control Valve. Any automatic or manually operated valve that controls the flow of water or air to any part of the system in the air or water supply. Control valves include gate and ball valves.

Ventilation-limited. An enclosure in which, under normal operating conditions, all doors, hatches, and service openings in the enclosure are closed and in which activation of the water mist system automatically stops the ventilation system supplying or exhausting air from the enclosure.

Water Mist.* A water spray for which the $Dv_{0.99}$, as measured at the coarsest part of the spray in a plane 3.3 ft (1 m) from the nozzle, at its minimum design operating pressure, is less than 1000 microns.

Water Mist Nozzle. A special purpose device containing one or more orifices designed to produce and deliver water mist.

Automatic Nozzles. Automatic nozzles shall operate independently of other nozzles by means of a detection/activation device built into the nozzle.

Nonautomatic Nozzles (Open). Nonautomatic nozzles shall operate as an entire system or grouping of nozzles. These nozzles contain open orifices and the water flow to the nozzles shall be activated by an independent detection system.

Hybrid Nozzles. A hybrid nozzle shall operate using a combination of the two methods described previously (automatic or nonautomatic means, or both). These nozzles contain a built-in detection/activation device that also can be activated by an independent detection system.

Water Mist System. A distribution system connected to a water supply or water and atomizing media supplies and equipped with one or more nozzles capable of delivering water mist intended to control, suppress, or extinguish fires and that has been demonstrated to meet the performance requirements of its listing and this standard.

Wet Pipe System. A water mist system using automatic nozzles attached to a piping system containing water and connected to a water supply so that water discharges immediately from nozzles operated by the heat from a fire.

Zoned Application System. A system designed to protect hazards in a predetermined portion of an enclosure.

1-4.2 Units.

1-4.2.1 Metric units of measurement in this standard are in accordance with the modernized metric system known as the International System of Units (SI). Liter and bar units are outside of but recognized by SI and are commonly used in international fire protection. These units are provided with their conversion factors in Table 1-4.2.2.

1-4.2.2 If a value for a measurement provided in this standard is followed by an equivalent value in other units, the first stated value shall be regarded as the requirement. A given equivalent value shall be considered an approximate value.

Table 1-4.2.2 Metric Conversion Factors

Name of Unit	Unit Symbol	Conversion Factor
Millimeter	mm	1 in. = 25.4 mm
Square meter	m^2	1 ft^2 = 0.0929 m^2
Liter	L	1 gal = 3.785 L
Cubic decimeter	dm^3	1 gal = 3.785 dm^3
Cubic meter	m^3	1 ft^3 = 0.028317 m^3

Kilogram	kg	1 lb = 0.4536 kg
Kilograms per cubic meter	kg/m^3	1 lb/ft^3 = 16.0183 kg/m^3
Pascal	Pa	1 psi = 6895 Pa
Bar	bar	1 psi = 0.0689 bars
Bar	bar	1 bar = 10^5 Pa
Liter per minute per square meter	$L/min/m^2$	1 gpm = 40.746 $L/min/m^2$
Micron	µ	1 mm = 1000µ (1000 microns)

NOTE 1: For additional conversions and information, see ASTM E 380, *Standard Practice for Use of the International System of Units (SI) (the Modernized Metric System).*

NOTE 2: In Canada, refer to CSA CAN3-A234.1, *Canadian Metric Practice Guide*.

NOTE 3: The abbreviation "gal" indicates the U.S. gallon measure.

1-5* General.

1-5.1

A water mist system is a fire protection system using very fine water sprays (i.e., water mist). The very small water droplets allow the water mist to control or extinguish fires by cooling of the flame and fire plume, oxygen displacement by water vapor, and radiant heat attenuation.

1-5.2 Use and Limitations.

1-5.2.1 Water mist systems are used for a wide range of performance objectives, including the following:

(a) Fire extinguishment;

(b) Fire suppression;

(c) Fire control;

(d) Temperature control; and

(e) Exposure protection.

1-5.2.2* Water mist systems shall not be used for direct application to materials that react with water to produce violent reactions or significant amounts of hazardous products. These materials include:

(a) Reactive metals, such as lithium, sodium, potassium, magnesium, titanium, zirconium, uranium and plutonium;

(b) Metal alkoxides, such as sodium methoxide;

(c) Metal amides, such as sodium amide;

(d) Carbides, such as calcium carbide;

(e) Halides, such as benzoyl chloride and aluminum chloride;

(f) Hydrides, such as lithium aluminum hydride;

(g) Oxyhalides, such as phosphorus oxybromide;

(h) Silanes, such as trichloromethylsilane;

(i) Sulfides, such as phosphorus pentasulfide; and

(j) Cyanates, such as methylisocyanate.

1-5.2.3 Water mist systems shall not be used for direct application to liquefied gases at cryogenic temperatures (such as liquefied natural gas), which boil violently when heated by water.

1-6 Safety.

1-6.1* Hazards to Personnel.

For fire situations, suitable safeguards shall be provided to ensure prompt evacuation of and to prevent entry into hazardous atmospheres and also to provide means for prompt rescue of any trapped personnel. Safety items such as personnel training, warning signs, discharge alarms, self-contained breathing apparatus, evacuation plans, and fire drills shall be considered.

1-6.2 Electrical Clearances.

NOTE: As used in this standard, "clearance" is the air distance between water mist system equipment, including piping and nozzles, and unenclosed or uninsulated live electrical components at other than ground potential. The minimum clearances provided are for the purpose of electrical clearance under normal conditions; they are not intended for use as "safe" distances during water mist system operation.

1-6.2.1* All system components shall be located to maintain minimum clearances from unenclosed and uninsulated energized electrical components in accordance with NFPA 70, *National Electrical Code*®.

1-6.2.2 Where the design basic insulation level (BIL) is not available and where nominal voltage is used for the design criteria, the highest minimum clearance specified for this group shall be used.

1-6.2.3 The selected clearance to ground shall satisfy the greater of the switching surges or BIL duty, rather than being based on nominal voltage.

1-6.2.4 The clearance between uninsulated energized parts of the electrical system equipment and any portion of the water mist system shall not be less than the minimum clearance provided elsewhere for electrical system insulation on any individual component.

1-7 Environmental Factors.

When selecting water mist to protect a hazard area, the effects of water runoff on the environment shall be considered. Particular attention shall be given to any water additives or any chemicals that can be carried out of the hazard area by the water.

Chapter 2 System Components and Hardware

2-1 General.

This chapter provides requirements for the correct use of water mist system components.

2-1.1

All components shall be listed for their intended use.

Exception No. 1: Where approval of system components is specifically permitted to be substituted for listing.

Exception No. 2: Where components are part of a listed, pre-engineered system.

2-1.2

System components shall be rated for the maximum working pressure to which they are exposed but not less than 175 psi (12.1 bar).

Exception: Where components are part of a listed, pre-engineered system with a self-contained water supply.

2-1.3 Corrosion Resistance.

Where components are subjected to severe corrosive atmospheres, corrosion protection such as special corrosion-resistive materials or coating shall be required.

2-2 Gas and Water Containers.

2-2.1 Capacity.

Gas and water containers, if provided, shall be sized to supply quantities of gas and water as required by Chapter 7.

2-2.2 Design.

2-2.2.1* Gas and water containers shall be designed for secure installation according to the manufacturer's installation manual, including provision for attachment of seismic restraint.

2-2.2.2* Gas and water containers shall be designed to meet the requirements of the U.S. Department of Transportation or of Transport Canada, if used as shipping containers. If not shipping containers, they shall be designed, fabricated, inspected, certified, and stamped in accordance with Section VIII of the ASME *Boiler and Pressure Vessel Code*. The design pressure shall be suitable for the maximum pressure developed by the water mist system at 130°F (54°C).

2-2.2.3 Each pressurized container shall be provided with a safety device to release excess pressure.

2-2.2.4 Each water container shall have a permanent nameplate or other permanent marking specifying the liquid held in the container (including additives) and the nominal water volume and pressurization level (where applicable) of the container.

Exception: Marking shall not be required on each water container if the information is provided on a nameplate or placard permanently installed on the system at a location convenient for servicing or content measuring.

2-2.2.5 External sight glasses on water containers shall be protected against mechanical damage.

2-2.2.6 Each gas container shall have a permanent nameplate or other permanent marking specifying the type of gas, weight of gas, weight of container, nominal gas volume, and pressurization level of the container.

Exception: Marking shall not be required on each gas container if the information is provided *on a nameplate or placard permanently installed on the system at a location convenient for servicing or content measuring.*

2-2.2.7 A reliable means shall be provided to indicate the pressure in refillable, pressurized gas containers.

2-2.3 Multiple Container Systems.

All containers supplying the same manifold outlet shall be interchangeable and of the same size and charge.

2-3 Piping and Tube.

2-3.1*

All piping from the system strainer to the nozzle shall have corrosion resistance at least equivalent to piping specified in Table 2-3.3.1. Wherever the word "pipe" is used, it shall be understood also to mean "tube."

2-3.2

Other types of pipe or tube investigated for suitability in water mist system installations and listed for this service shall be permitted where installed in accordance with their listing limitations, including installation instructions. Bending of the pipe shall be permitted as provided by the listing. Pipe or tube shall not be listed for portions of an occupancy classification.

2-3.3 Low Pressure Systems.

2-3.3.1 Pipe or tube used in low pressure water mist systems shall meet or exceed one of the standards in Table 2-3.3.1 or shall be in accordance with 2-3.2. The chemical properties, physical properties, and dimensions of the materials given in Table 2-3.3.1 shall conform at a minimum to the standards cited in the table. Pipe and tube used in water mist systems shall be designed to withstand a working pressure of not less than 175 psi (12.1 bar).

Table 2-3.3.1 Pipe or Tube Standards

Materials and Dimensions	Standard
Copper Tube (Drawn, Seamless)	
Standard Specification for Solder Metal [95-5 (Tin-Antimony-Grade 95TA)]	ASTM B 32
Standard Specification for Seamless Copper Tube[1]	ASTM B 75
Standard Specification for Seamless Copper Water Tube[1]	

	ASTM B 88
Standard Specification for General Requirements for Wrought Seamless Copper and Copper-Alloy Tube	ASTM B 251
Standard Specification for Liquid and Paste Fluxes for Soldering Applications of Copper and Copper-Alloy Tube	ASTM B 813
Specification for Filler Metals for Brazing and Braze Welding (Classification BCuP-3 or BCuP-4)	AWS A5.8
Stainless Steel	
Standard Specification for Seamless and Welded Austenitic Stainless Steel Tubing for General Service	ASTM A 269
Standard Specification for Seamless and Welded Austenitic Stainless Steel Tubing (Small-Diameter) for General Service	ASTM A 632
Standard Specification for Welded, Unannealed Austenitic Stainless Steel Tubular Products	ASTM A 778
Standard Specification for Seamless and Welded Ferritic/ Austenitic Stainless Steel Tubing for General Service	ASTM A 789/A 789M

[1]Denotes pipe or tube suitable for bending (*see 2-3.6*) according to ASTM standards.

2-3.3.2 Copper tube as specified in the standards referenced in Table 2-3.3.1 shall have a wall thickness of Type K, L, or M where used in water mist systems.

2-3.4 Intermediate and High Pressure Systems.

2-3.4.1 Pipe or tube shall be of noncombustible material having physical and chemical characteristics such that its deterioration under stress can be predicted with reliability. The piping shall be in accordance with ANSI B31.1, *Power Piping Code*. The internal pressure used for calculation of pipe wall thickness shall be the maximum operating pressure of the water mist systems at a pipe temperature of 130°F (54°C).

2-3.4.2* Flexible piping, tubing, or hoses (including connections) shall be listed for their intended use.

2-3.5 Pipe or Tube Identification.

2-3.5.1 All pipe or tube, including specially listed pipe or tube, shall be marked continuously along its length by the manufacturer in such a way as to identify the type of pipe or tube properly. This identification shall include the manufacturer's name, model designation, or schedule.

2-3.5.2 Pipe or tube marking shall not be painted, concealed, or removed prior to approval by the authority having jurisdiction.

2-3.6 Pipe or Tube Bending.

Bending of Type K and Type L copper tube shall be permitted where bends are made with no kinks, ripples, distortions, reductions in diameter, or any noticeable deviations from a round shape. The minimum radius of a bend shall be six pipe diameters for pipe sizes of 2 in. (51 mm) and smaller and five pipe diameters for pipe sizes larger than 2 in. (51 mm).

2-4 Fittings.

2-4.1* General.

All fittings used on piping described in 2-3.1 shall have a corrosion resistance at least equivalent to wrought copper fittings conforming to ANSI B16.22, *Wrought Copper and Copper Alloy Solder Joint Pressure Fittings*.

2-4.2 Low Pressure Systems.

2-4.2.1 Fittings used in water mist systems shall meet or exceed the standards in Table 2-4.2.1 or shall be in accordance with 2-4.2.2.

Table 2-4.2.1 Fitting Standards

Materials and Dimensions	Standard
Copper	
Cast Copper Alloy Solder Joint Pressure Fittings	ANSI B16.18
Wrought Copper and Copper Alloy Solder Joint Pressure Fittings	ANSI B16.22
Stainless Steel	
Standard Specification for Castings, Austenitic, Austenitic-Ferritic (Duplex) for Pressure-Containing Parts	ASTM A 351/A 351M
Standard Specification for Wrought Austenitic Stainless Steel Piping Fittings	ASTM A 403/A 403M
Standard Specification for As-Welded Wrought Austenitic Stainless Steel Fittings for General Corrosive Service at Low and Moderate Temperatures	ASTM A 774/A 774M
Standard Specification for Wrought Ferritic, Ferritic/Austenitic, and Martensitic Stainless Steel Piping Fittings	ASTM A 815/A 815M

2-4.2.2* Other types of fittings investigated for suitability in water mist installations and listed for this service shall be permitted where installed in accordance with their listing limitations, including installation instructions.

2-4.2.3 Screwed unions shall not be used on pipe larger than 2 in. (51 mm). Couplings and unions of other than the screwed type shall be listed for the intended use.

2-4.2.4 A one-piece reducing fitting shall be used wherever a change is made in the size of pipe.

Exception: Hexagonal or face bushings shall be permitted in reducing the size of openings of fittings where standard fittings of the required size are not available.

2-4.2.5 All threads used in joints and fittings shall conform to ANSI B1.20.1, *Pipe Threads, General Purpose (Inch)*. Joint compound, tape, or thread lubricant shall be applied only to the male threads of the joint.

2-4.2.6 Soldering fluxes shall be in accordance with Table 2-3.3.1. Brazing fluxes, if used, shall not be of a highly corrosive type.

2-4.2.7 Welding shall be performed in accordance with AWS D10.9, *Specification for Qualification of Welding Procedures and Welders for Piping and Tubing*, Level AR-3.

2-4.3 Intermediate and High Pressure Systems.

2-4.3.1 Fittings shall have a minimum-rated working pressure equal to or greater than the maximum operating pressure of the water mist systems at 130°F (54°C). For systems that employ the use of a pressure regulating device in the distribution piping, the fittings downstream of the device shall have a minimum-rated working pressure equal to or greater than the maximum anticipated pressure in the downstream piping.

2-4.3.2 All threads used in joints and fittings shall conform to ANSI B1.20.1, *Pipe Threads, General Purpose (Inch)*. Joint compound, tape, or thread lubricant shall be applied only to the male threads of the joint.

2-4.3.3 Welding and brazing alloys shall have a melting point above 1000°F (538°C).

2-4.3.4 Welding and brazing shall be performed in accordance with Section IX of the ASME *Boiler and Pressure Vessel Code*.

2-4.3.5 Where copper, stainless steel, or other suitable tubing is joined with compression-type fittings, the manufacturer's pressure temperature ratings for the fitting shall not be exceeded.

2-5 Hangers.

2-5.1

Hangers shall be listed for use with the pipe or tube involved.

Exception: Hangers certified by a registered professional engineer to include the following shall be permitted where:

(a) Hangers are designed to support five times the weight of the pipe or tube when filled with gas or water, as appropriate, plus 250 lb (114 kg) at each point of piping support;

(b) These points of support are adequate to support the water mist system; and

(c) Hanger components are ferrous.

Detailed calculations shall be submitted, where required by the authority having jurisdiction, showing the stresses developed both in the hangers and the piping and the safety factors provided.

2-5.2

Hanger components shall be ferrous.

Exception: Nonferrous components that have been proven by fire tests to be adequate for the hazard application, that are listed for this purpose, and that are in compliance with the other requirements of this section shall be permitted.

2-5.3

The components of hanger assemblies that attach directly to the pipe or to the building structure shall be listed. Threaded portions of hangers shall not be bent.

Exception: Mild steel rods that connect pipe and building attachment components shall be permitted to be of an approved type.

2-5.4

The use of listed inserts set in concrete to support hangers shall be permitted.

2-5.5

Power-driven fasteners shall not be used to attach hangers to the building structure where systems are required to be protected against earthquakes.

Exception: Power-driven fasteners shall be permitted where they are specifically listed for service in seismic areas.

2-6 Nozzles.

2-6.1*

Nozzles shall be listed either individually or as a part of a pre-engineered system. Listing information shall include:

(a) Specific hazards and protection objectives;

(b) Volumetric flow rate characteristics of water discharge for each nozzle;

(c) Maximum height of protected space;

(d) Minimum distance between nozzle tip or diffuser, as applicable, and plane of protection;

(e) Maximum spacing between nozzles;

(f) Maximum coverage area per nozzle;

(g) Minimum spacing between nozzles;

(h) Maximum height between ceiling and nozzle diffuser or tip, as applicable;

(i) Nozzle obstruction spacing criteria;

(j) Maximum spacing of nozzles from walls;

(k) Minimum- and maximum-rated operating pressures of nozzles;

(l) Allowable range of nozzle orientation angle from vertically down;

(m) Classification of automatic nozzle thermal response characteristics as fast, special, or standard response;

(n) Maximum compartment volume, if applicable; and

(o) The maximum time delay for water mist delivery to the most remote nozzle.

2-6.2

Only new nozzles shall be installed in water mist systems.

2-6.3

Nozzles shall be permanently marked to identify the manufacturer, type, and size of the orifice(s) or part number.

2-6.4

Additional corrosion protection, such as special corrosion-resistant materials or coatings, shall be required in severely corrosive atmospheres. Where protective coatings are used to meet the requirements of 2-1.3, the coatings shall be applied by the nozzle manufacturer and the coated nozzle shall be listed.

2-6.5

Where clogging by external, foreign materials is likely, discharge nozzles shall be provided with frangible discs, blow-off caps, or other suitable devices. These devices shall provide an unobstructed opening upon system operation and shall be located so they cannot injure personnel.

2-6.6

The standard temperature ratings of individual, thermally activated nozzles are shown in Table 2-6.6. Individual, thermally activated nozzles shall be colored in accordance with the color code designated in Table 2-6.6.

Table 2-6.6 Temperature Ratings, Classifications, and Color Coding of Individual, Thermally Activated Nozzles

Maximum Ambient Temperature		Nozzle Temperature Rating		Temperature	Color	Glass Bulb
(°F)	(°C)	(°F)	(°C)	Classification	Code	Colors
100	38	135 to 170	57 to 77	Ordinary	Uncolored or black	Orange or red
150	66	175 to 225	79 to 107	Intermediate	White	Yellow or green
225	107	250 to 300	121 to 149	High	Blue	Blue
300	149	325 to 375	163 to 191	Extra high	Red	Purple
375	191	400 to 475	204 to 246	Very extra high	Green	Black
475	246	500 to 575	260 to 302	Ultra high	Orange	Black
625	329	650	343	Ultra high	Orange	Black

2-6.7

The stock of spare, individual, thermally activated nozzles shall include all types and ratings installed and shall be as follows:

(a) For systems having fewer than 50 nozzles, not fewer than 3 nozzles;

(b) For systems having 50 to 300 nozzles, not fewer than 6 nozzles;

(c) For systems having 301 to 1000 nozzles, not fewer than 12 nozzles; and

(d) For systems having over 1000 nozzles, not fewer than 24 nozzles.

2-7 Valves.

2-7.1

All valves shall be listed for their intended use.

Exception: Valves used only for drains or test connections shall be permitted to be approved.

2-7.2

All gaskets, O-rings, sealants, and other valve components shall be constructed of materials that are compatible with the gas or water and any additives contained in the water.

2-7.3 Identification of Valves.

All control, drain, and test connection valves shall be provided with permanently marked, weatherproof, metal or rigid plastic identification signs. The sign shall be secured with corrosion-resistant wire, chain or other approved means.

2-8 Strainers and Filters.

2-8.1

Pipeline strainers and filters shall be listed for use in water supply connections.

2-8.2

The strainer or filter shall be capable of continued operation without serious increase in head loss for a period that is estimated to be ample, taking into account the type of protection provided, the condition of the water, and similar local circumstances.

2-8.3

Pipeline strainer and filter designs shall incorporate a flush-out connection.

2-8.4

Pipeline strainers and filters shall be sized in accordance with 7-5.1.2 and 7-5.1.4.

2-8.5

Individual strainers or filters for water mist nozzles, where required by the manufacturer, shall be listed as a part of a nozzle.

2-8.6

A stock of spare pipeline and individual nozzle strainers and filters for water mist nozzles shall be provided and shall include all types and sizes installed. Sufficient spare strainers and filters shall be provided to service the nozzles for the largest single hazard or group of hazards to be protected simultaneously.

2-9 Pumps.

2-9.1 Materials.

2-9.1.1 Pumps shall be designed with capacities in accordance with 7-5.2.

2-9.1.2 Pumps capable of overpressurizing the system shall be provided with adequate means of pressure relief from the discharge to the supply side of the pump to prevent excessive pressure and temperature. Overpressure shall not exceed the working pressure of the piping system.

2-9.1.3 Pumps shall start automatically upon system actuation.

2-9.1.4 Provisions shall be made for automatic shutoff of the pump after the water supply is exhausted.

2-9.1.5 Pumps shall not take suction under a static lift condition.

2-9.2 Power Supply.

2-9.2.1 The power supply for pump drivers shall be installed in accordance with NFPA 20, *Standard for the Installation of Centrifugal Fire Pumps*, and NFPA 70, *National Electrical Code*.

Exception: Power supplies shall not be required to be fed by an independent service feed.

2-9.2.2 Power supplies shall be arranged so that disconnecting power to the protected facility during a fire shall not disconnect the power supply to the pump feeder circuit.

2-9.3 Controllers.

2-9.3.1 Controllers for pumps shall be listed as follows:

(a) Electric drive pumps greater than 30 horsepower, use listed fire pump controller;

(b) Electric drive pumps greater than 15 horsepower but not exceeding 30 horsepower, use listed fire pump controller or use listed limited service controller;

(c) Electric drive pumps less than 15 horsepower, use listed limited service controller; and

(d) Diesel engine drive pumps, use listed fire pump controller.

2-9.3.2 A service-disconnecting means in the feeder circuit to limited service controllers shall be permitted where acceptable to the authority having jurisdiction, provided the disconnecting means is supervised for the proper position. Supervision for proper position shall be by one of the following methods:

(a) Central station, proprietary, or remote station signaling electrical supervision service; or

(b) Local electrical supervision through use of a signaling service that causes the sounding of an audible signal at a constantly attended location; or

(c) Locking of the disconnecting means in the proper position, with monthly recorded inspections.

2-10 Detection, Actuation, Alarm, and Control Systems.

2-10.1 General.

2-10.1.1 Detection, actuation, alarm, and control systems shall be installed, tested, and maintained in accordance with appropriate, protective, signaling systems standards as follows:

NFPA 70, *National Electrical Code*;

NFPA 72, *National Fire Alarm Code*;

CAN/ULC S524-M86, *Standard for the Installation of Fire Alarm Systems (in Canada)*; and

CAN/ULC S529-M87, *Smoke Detectors for Fire Alarm Systems (in Canada)*.

2-10.1.2 Where a detection system is used to actuate the water mist system, detection and actuation shall be automatic.

Exception: Manual-only actuation shall be permitted if approved by the authority having jurisdiction.

2-10.2 Automatic Detection.

2-10.2.1* Automatic detection shall be by listed equipment installed in accordance with NFPA 72, *National Fire Alarm Code*.

2-10.2.2 Adequate and reliable primary and 24-hour minimum standby sources of energy shall be used to provide for operation of the detection, signaling, control, and actuation requirements of the systems.

2-10.2.3 If an existing detection system is used in a new water mist system, the detection system shall comply with the requirements of this standard.

2-10.3 Operating Devices.

2-10.3.1 Operating devices shall include water mist releasing devices or valves, discharge controls, and shutdown equipment necessary for successful performance of the system.

2-10.3.2 Operation shall be by listed mechanical, electrical, or pneumatic equipment. An adequate and reliable source of energy shall be used.

2-10.3.3 Devices shall be designed for the service they are to encounter and shall not readily be rendered inoperative or susceptible to accidental operation. Devices shall be designed to function properly from –20°F to 130°F (–29°C to 54°C) or shall be marked to indicate temperature limitations.

2-10.3.4 An emergency release of the system that can be achieved by a single manual operation shall be provided. This shall be accomplished by a mechanical manual release or by an electrical, manual release when the control equipment that monitors the battery voltage level of the standby battery supply indicates a low battery signal. The release shall cause simultaneous operation of automatically operated valves that control agent release and distribution. The battery shall be sized to accomplish all functions.

Exception: Dry and wet pipe systems utilizing individual, thermally activated nozzles.

2-10.3.5 The normal manual control(s) for actuation shall be located for easy accessibility at all times, including at the time of a fire. The manual control(s) shall be of distinct appearance and clearly recognizable for the purpose intended. Operation of any manual control shall cause the complete system to operate in its normal fashion.

2-10.3.6 Manual controls shall not require a force of more than 40 lbf (178 N) nor a movement of more than 14 in. (356 mm) to secure operation. At least one manual control for activation shall be located not more that 4 ft (1.2 m) above the floor.

2-10.3.7 All devices for shutting down supplementary equipment shall be considered integral parts of the system and shall function with the system in operation.

2-10.3.8 All manual devices shall be identified as to the hazard they protect.

2-10.4 Control Equipment.

2-10.4.1 Electrical Control Equipment. Automatic control equipment shall be listed and installed in accordance with NFPA 72, *National Fire Alarm Code*.

2-10.4.2 The control unit shall be listed for release device service.

2-10.4.3 Pneumatic Control Equipment.

2-10.4.3.1 Pneumatic control lines shall be protected against crimping and mechanical damage. Where installations could be exposed to conditions that could lead to loss of integrity of the pneumatic lines, special precautions shall be taken to ensure that no loss of integrity occurs. Pneumatic control lines used as part of the system actuation shall be supervised.

Exception No. 1: Pneumatically operated control lines immediately adjacent to the pressurizing source are not required to be supervised.

Exception No. 2: Pneumatic control lines from master to slave cylinders which are located in close proximity to one another are not required to be supervised.

2-10.4.3.2 The control equipment shall be specifically listed for the number and type of actuating devices utilized, and their compatibility shall have been listed.

2-11 Unwanted System Operation.

Care shall be taken to thoroughly evaluate and correct any factors that could result in unwanted system discharge.

2-12 Compatibility.

All components of pneumatic, hydraulic, or electrical systems shall be compatible.

Chapter 3 System Requirements

3-1 General.

Water mist systems shall be described by the following four parameters:

(a) System application;

(b) Nozzle type;

(c) System operation method; and

(d) System media type.

3-2 System Applications.

System applications shall consist of the following three categories:

(a) Local application systems;

(b) Total compartment application systems; or

(c) Zoned application systems.

3-2.1 Local Application Systems.

Local application systems are designed and installed to provide complete distribution of mist around the hazard or object to be protected.

3-2.1.1 Local application systems shall be designed to protect an object or a hazard in an enclosed, unenclosed, or open outdoor condition.

3-2.1.2 Local application systems shall be actuated by automatic nozzles or by an independent detection system.

3-2.2 Total Compartment Application Systems.

Total compartment application systems are designed and installed to provide complete protection of an enclosure or space.

3-2.2.1* The complete protection of an enclosure or space shall be achieved by the simultaneous operation of all nozzles in the space by manual or automatic means.

3-2.3 Zoned Application Systems.

Zoned application systems are a subset of the compartment system and are designed to protect a predetermined portion of the compartment by the activation of a selected group of nozzles.

3-2.3.1 Zoned application systems shall be designed and installed to provide complete mist distribution throughout a predetermined portion of an enclosure or space. This shall be achieved by simultaneous operation of a selected group of nozzles in a predetermined portion of the space by manual or automatic means.

3-2.3.2 Zoned application systems shall be actuated by automatic nozzles or by an independent detection system.

3-3 Nozzle Types.

Water mist nozzles shall be classified as one of the following three types:

(a) Automatic;

(b) Nonautomatic; and

(c) Hybrid.

3-4 System Operation Methods.

Water mist systems shall operate by means of one of the following methods:

(a) Deluge;

(b) Wet pipe;

(c) Preaction; and

(d) Dry pipe.

3-4.1 Deluge Systems.

Deluge systems shall employ nonautomatic nozzles (open) attached to a piping network connected to the fluid supply(ies) through a valve controlled by an independent detection system installed in the same area as the mist nozzles. When the valve(s) is activated, the fluid shall flow into the piping network and discharge from all nozzles attached thereto.

3-4.2 Wet Pipe Systems.

Wet pipe systems shall employ automatic nozzles attached to a piping network pressurized with water up to the nozzles.

3-4.3 Preaction Systems.

Preaction systems shall employ automatic nozzles attached to a piping network containing a pressurized gas with a supplemental, independent detection system installed in the same area as the nozzles. Operation of the detection system shall actuate a tripping device that opens the valve, pressurizing the pipe network with water to the nozzles.

3-4.4 Dry Pipe Systems.

Dry pipe systems shall employ automatic nozzles attached to a piping network containing a pressurized gas. The loss of pressure in the piping network shall activate a control valve, which causes water to flow into the piping network and out through the activated nozzles.

3-5* Media System Types.

Water mist systems shall be classified by two media system types:

(a) Single fluid; or

(b) Twin fluid.

3-5.1

Twin fluid media systems produce water mist (droplet production) by exposing a slow-moving liquid to a higher velocity atomizing fluid stream. The process shall occur in or near the discharge nozzle.

Chapter 4 Installation Requirements

4-1 General.

This chapter provides requirements for the correct installation of water mist system components.

4-1.1

All listed materials and devices shall be installed in accordance with their listing. All other materials and devices shall be installed in accordance with the system design manual. Systems installed in corrosive environments shall comply with 2-1.3.

4-1.2

System components shall be located, installed, or suitably protected so they are not subject to mechanical, chemical, or other damage that could render them inoperative.

4-2 Nozzles.

4-2.1 General.

Nozzles shall be installed in accordance with the manufacturer's listing.

4-2.2 Nozzle Height Limitations.

The minimum and maximum heights shall be in accordance with the manufacturer's listing.

4-2.3 Nozzle Spacing Limitations.

The minimum and maximum distances between nozzles shall be in accordance with the manufacturer's listing.

4-2.4 Distance from Walls.

The minimum and maximum distance from nozzles to walls or partitions shall be in accordance with the manufacturer's listing.

4-2.5 Obstructions to Nozzle Discharge.

The location of nozzles with respect to obstructions shall be in accordance with the manufacturer's listing.

4-2.6 Distance Below Ceilings.

The distance between the nozzle and the ceiling shall be in accordance with the range (minimum and maximum) identified in the manufacturer's listing.

4-2.7 Spacing under Pitched or Curved Surfaces.

The distance between nozzles in or under a pitched or curved surface shall be in accordance with the manufacturer's listing.

4-2.8 Nozzle Protection.

Nozzles subject to mechanical damage shall be protected with listed guards. Guards shall not significantly reduce the effectiveness of the nozzle.

4-2.9 Escutcheon Plates.

4-2.9.1 Escutcheon plates used in a recessed or flush-type nozzle installation shall be a part of a listed nozzle assembly.

4-2.9.2 Nonmetallic escutcheon plates shall be listed.

4-2.10 Thermally Activated Nozzle Temperature Ratings.

4-2.10.1 Ordinary temperature-rated nozzles shall be used unless otherwise specified.

4-2.10.2 The following practices shall be observed where providing automatic nozzles of other than ordinary temperature classification unless other temperatures are determined or unless high temperature nozzles are used throughout.

(a) Automatic and hybrid nozzles installed in a heater zone shall be of the high temperature classification, and nozzles in the danger zone shall be of the intermediate temperature classification.

(b) Automatic and hybrid nozzles located within 12 in. (305 mm) to one side of or 30 in. (762 mm) above an uncovered steam main, heating coil, or radiator shall be of the intermediate temperature classification.

(c) Automatic and hybrid nozzles within 7 ft (2.1 m) of a low pressure blow-off valve that discharges freely in a larger room shall be of the high temperature classification.

(d) Automatic and hybrid nozzles installed under glass or plastic skylights exposed to the direct rays of the sun shall be of the intermediate temperature classification.

(e) Automatic and hybrid nozzles installed in an unventilated, concealed space, under an insulated roof, or in an unventilated attic shall be of the intermediate temperature classification.

(f) Automatic and hybrid nozzles installed in unventilated areas having high-powered electric lights near the ceiling shall be of the intermediate temperature classification.

(g) Automatic and hybrid nozzles protecting commercial-type cooking equipment and ventilation systems shall be of the high or extra-high temperature classification as determined by use of a temperature measuring device.

4-3 Pipe and Tubing.

4-3.1

Piping and tubing for water mist systems shall be installed in accordance with the manufacturer's installation manual.

4-3.1.1 All water and atomizing media piping and tubing for water mist systems shall be installed in accordance with ANSI B31.1, *Power Piping Code*.

Exception No. 1: Piping in low pressure systems installed in accordance with NFPA 13, Standard for the Installation of Sprinkler Systems. This exception does not apply to piping conveying atomizing media.

Exception No. 2: Piping installed in accordance with a water mist system listing where the listing provides installation criteria different from ANSI B31.1, Power Piping Code.

4-3.1.2 All system piping, tubing, and hoses shall be rated for the maximum working pressure to which they are exposed.

4-3.1.3 Any flexible piping, tubing, hoses, or combination thereof shall be constructed and installed in accordance with the manufacturer's listing.

4-3.2

The system piping shall be supported by structural elements that are independent of the ceiling sheathing to prevent lateral and horizontal movement upon system actuation.

4-3.3

All system piping and fittings shall be installed so that the entire system can be drained.

4-3.4 Location of Hangers and Supports.

Hangers and supports shall be located in accordance with the system's design manual.

Exception: For low pressure and intermediate systems, steel pipe and copper tubing shall be supported in accordance with NFPA 13, Standard for the Installation of Sprinkler Systems.

4-3.4.1 The length of an unsupported arm over to a nozzle shall not exceed 2 ft (0.6 m) for steel pipe or 1 ft (0.3 m) for steel tubing.

4-3.5 Protection of System Components against Damage where Subject to Earthquakes.

Water mist systems shall be protected to prevent pipe breakage where subject to earthquakes in accordance with 4-14.4.3 of NFPA 13, *Standard for the Installation of Sprinkler Systems*.

4-4 Fittings.

4-4.1

All system fittings shall be installed in accordance with the manufacturer's listing.

Exception: All fittings installed in low pressure water mist systems shall conform to NFPA 13, Standard for the Installation of Sprinkler Systems.

4-4.2

All fittings shall be rated for the maximum working pressure to which they are exposed.

4-5 Gas and Water Storage Containers.

4-5.1

Storage containers shall be installed, mounted, and braced in accordance with the manufacturer's listing.

4-5.2

Storage containers and accessories shall be installed so that inspection, testing, recharging, and other maintenance are facilitated and interruption to protection is held to a minimum.

4-5.3*

Storage containers shall be located as close as possible to the hazard or within the hazards they protect, and shall not be exposed to fire or mechanical damage in a manner to affect performance.

4-5.4

Storage containers shall be protected from severe weather conditions and from mechanical, chemical, or other damage.

4-5.4.1 Where excessive climatic or mechanical exposures are expected, guards or enclosures shall be provided.

4-5.5 High Pressure Storage Containers.

4-5.5.1 High pressure containers or cylinders shall be constructed, tested, and marked in accordance with recognized, international standards, such as the U.S. Department of Transportation, Title 49, *Code of Federal Regulations*, Parts 171 to 190, Sections 178.36 and 178.37, specifications (in effect upon date of manufacture and test) for DOT-3A, 3AA-1800, or higher, seamless steel cylinders. Charged cylinders shall be tested for tightness before shipment in accordance with an approved procedure.

4-5.5.2 Where manifolded, cylinders shall be adequately mounted and suitably supported in a rack provided for this purpose, including facilities for convenient, individual servicing or weighing of contents. When any cylinder is removed for maintenance, automatic means shall be provided to prevent leakage from the manifold if the system is operated.

4-5.5.3 Storage temperatures shall be maintained within the range specified in the manufacturer's listing. External heating or cooling shall be an acceptable method to keep the temperature of the storage container within desired ranges.

4-5.5.4 Containers shall be secured with manufacturer listed supports to prevent container movement and possible physical damage.

4-5.6 Low Pressure Storage Cylinders.

4-5.6.1 The pressure container shall be made, tested, approved, equipped, and marked in accordance with recognized, international standards, such as the current specifications of the ASME *Boiler and Pressure Vessel Code*, Section VIII, or the requirements of U.S. Department of Transportation, Title 49, *Code of Federal Regulations*, Parts 171 to 190, Sections 178.36 and 178.37, or both. The design working pressure shall be in accordance with the manufacturer's listing.

Exception: Pressure containers for heated water mist systems shall be in accordance with the manufacturer's listing.

4-5.6.2 Each pressure container shall be equipped with a liquid level gauge, a pressure gauge, and a high/low pressure supervisory alarm set at the values identified in the manufacturer's listing.

Exception: Media storage containers that become pressurized only during system activation shall not require high/low pressure supervisory alarms.

4-5.7

Storage temperatures shall be maintained within the range specified in the manufacturer's listing. External heating or cooling shall be an acceptable method to keep the temperature of the storage container within desired ranges.

4-5.7.1 Containers shall be secured with manufacturer-listed supports to prevent container movement and possible physical damage.

4-6 Pumps and Pump Controllers.

4-6.1*

Pumps shall be sized to provide 120 percent of the required system water flow rate, at the minimum system operating pressure, as determined by hydraulic calculations.

4-6.2

Pumps shall start automatically and shall supply water to the water mist system until manually shut off or automatically shut off in accordance with the manufacturer's listing.

4-6.3

Power supplies for system pumps shall meet the requirements specified in NFPA 20, *Standard for the Installation of Centrifugal Fire Pumps*, or shall be in accordance with the manufacturer's listing.

4-6.4

Pumps shall be provided with supervisory service from a listed central station, proprietary, or remote station system or equivalent.

Exception: Pumps for single family dwellings.

4-7 Strainers and Filters.

4-7.1

Strainers and filters shall be provided at all water supply connections in accordance with Chapter 7. Filters and strainers shall be installed to minimize potential head loss due to accumulation of particulates.

4-8 Valves and Pressure Gauges.

4-8.1 General.

4-8.1.1 All valves shall be installed in accordance with the manufacturer's listing.

4-8.1.2 Valves having components that extend beyond the valve body shall be installed in a manner that does not interfere with the operation of any system components.

4-8.1.3 All valves shall be listed for their particular application and installation.

4-8.1.4 All control, drain, and test connection valves shall be provided with permanently marked, weatherproof, metal or rigid plastic identification signs. The sign shall be secured by corrosion-resistant wire or chain or by other approved means.

4-8.1.5 System valves and gauges shall be installed such that they are accessible for operation, inspection, and maintenance.

4-8.1.6 At least one listed indicating valve shall be installed in each source of water supply.

Exception: Systems with a single water supply source composed of a self-contained system (cylinders, containers).

4-8.1.7 Valves on connections to water supplies, sectional control valves, and other valves in supply pipes to nozzles shall be locked open or equipped with tamper-monitoring devices.

Exception: Normally closed, automatic water control valves.*

4-8.2 Control/Activation Valves.

4-8.2.1 Control/activation valves shall include any device or valve that automatically opens to supply water to the nozzles after the detection of a fire.

4-8.2.2 Control/activation valves shall operate by a listed mechanical, electrical, or pneumatic means. An adequate and reliable source of energy shall be used.

4-8.2.3 Control/activation valves shall be installed such that they are not subject to mechanical, chemical, or other damage that would render them inoperative.

4-8.3 Pressure Regulating and Pressure Relief Valves.

4-8.3.1 Water Pressure Regulating Valves.

4-8.3.1.1 Pressure regulating valves shall be installed in any portion of the system where the potential exists for the system pressure to exceed the maximum-rated working pressure of the system or system components, or both. These valves shall open when the system pressure reaches 95 percent of the system-rated pressure.

4-8.3.1.2 A relief valve of not less than $^1/_2$ in. (13 mm) shall be provided on the discharge side of the pressure regulating valve that is set to operate at a pressure not exceeding the system-rated pressure.

4-8.3.1.3 A listed indicating valve shall be provided on the inlet side of each pressure reducing valve.

Exception: A listed indicating valve shall not be required where the pressure regulating valve meets the listing requirements for use as an indicating valve.

4-8.3.1.4 A water flow test valve that is sized to produce the designed flow of the pressure reducing valve shall be installed on the downstream side of the pressure reducing valve.

4-8.3.1.5 A sign indicating the correct discharge pressure for static and residual pressures shall be attached to the pressure reducing valve.

4-8.3.2 Compressed Gas Pressure Regulating Valves (PRVs).

4-8.3.2.1 PRVs shall be installed in accordance with the manufacturer's listing.

4-8.3.2.2 PRVs shall be installed when the supply pressure is higher than the design operating pressure of the water mist system.

4-8.3.2.3 PRVs shall be capable of providing a stable regulating output at the rated flow capacity and design set point over the full range of input pressures that will be experienced over the course of the discharge period.

4-8.3.2.4 Downstream pressure drift under no-flow conditions shall not exceed the lesser of the downstream components pressure rating or the pressure relief valve set point, if provided.

4-8.3.2.5 Pressure set, point-adjusting mechanisms on the PRVs shall be tamper resistant, and the adjustment shall be indicated by a permanent marking. A means to indicate evidence of tampering shall be provided.

4-8.3.2.6 The PRVs set point shall be set by the manufacturer.

4-8.3.2.7 Permanent markings shall indicate the inlet and outlet connections of the PRVs.

4-8.4 Check Valves and Backflow Preventers.

4-8.4.1 Check valves shall be installed in accordance with the manufacturer's listing.

4-8.4.2 A check valve shall be installed between the system and the point of permanent connection to a potable water supply.

Exception: Where additives are used in the water mist system, either by injection into flowing lines or by premixing into stored water sources, a backflow preventer shall be installed between the system control valve or stored water supply and a permanent connection to a potable water supply.

4-8.4.3 Check valves shall be installed in the main feed lines, near the control valves of both the water and pneumatic system piping of a twin fluid system, to prevent the backflow of water or atomizing fluid into the companion piping.

4-8.5 Pressure Gauges.

4-8.5.1 Pressure gauges shall be installed in the following locations:

(a) On both sides of a pressure regulating valve;

(b) On the pressurized side of all supply connections;

(c) On the pressurized side of all system control valves;

(d) On all pressurized storage containers; and

(e) On all air supplies for dry pipe and preaction systems.

4-8.5.2 The required pressure gauges shall be compatible with their intended use and shall have an operating range not less than twice the normal working pressure of the system.

4-9 Electrical Systems.

4-9.1 Electrical Equipment.

4-9.1.1 Water mist systems shall be installed in accordance with the requirements of NFPA 70, *National Electrical Code.*

4-9.1.2* All signaling system circuits and wiring shall be installed in accordance with NFPA 72, *National Fire Alarm Code.*

4-9.2 Control Equipment.

4-9.2.1 Electrical fire detection and control equipment used to activate water mist systems shall be installed in accordance with NFPA 70, *National Electrical Code;* NFPA 72, *National Fire Alarm Code* or equivalent; or the manufacturers' recommendations, as appropriate.

4-9.2.2 All circuitry that is monitoring or controlling the water mist system shall be electrically supervised in accordance with NFPA 72, *National Fire Alarm Code*.

4-9.2.3 Adequate and reliable primary and 24-hour minimum standby sources of energy shall be used to provide for operation of the detection, signaling, control, and actuation requirements of the system.

4-9.2.4 Alarms shall be provided to indicate system activation or system trouble conditions, or both. Trouble and supervisory signals shall include power failure, operation (closing) of monitored valving, and electrical faults in the detection/activation of pump power control systems. These alarms shall be both visible and audible inside the protected space, at the location of the primary system components (e.g., pumps, storage tanks), and in a continuously attended location. The system activation alarm shall be distinctly different from the system trouble signal to prevent confusion.

4-9.3 Fire Detection.

4-9.3.1* When electrically operated automatic fire detection systems are used, the installation shall be in accordance with NFPA 72, *National Fire Alarm Code*.

4-9.3.2 Adequate and reliable primary and 24-hour minimum standby sources of energy shall be used to provide for operation of the detection, signaling, control, and actuation requirements of the system.

4-9.3.3 Where a new water mist system is installed in a space that has an existing detection system, an analysis shall be made of the detection devices to ensure that the detection system meets the requirements of the water mist system listing and that the detection system is in good operating condition.

4-9.4 Automatic and Manual Activation.

4-9.4.1 A means of automatic operation of the water mist system shall be provided. This shall be accomplished by means of automatic nozzles (independently thermally activated), automatic group control valves, or an independent automatic fire detection system, coupled with a listed system activation panel.

Exception: Manual-only actuation shall be permitted if approved by the authority having jurisdiction.

4-9.4.2 A means of manual release of the system shall be installed and arranged in accordance with 2-10.3.

Chapter 5 Design Objectives and Hazard Classifications

5-1 General. Currently, no general design method is recognized for water mist protection systems. Water mist protection systems shall be designed and installed in accordance with their listing for the specific hazards and protection objectives specified in the listing. The characteristics of the specific application (compartment variables and hazard classification) shall be consistent with the listing of the system. The compartment geometry, fire hazard, and system variables described in this chapter shall be considered adequate to ensure that the system design and installation are consistent with the system listing.

5-1.1

The fire-fighting performance objectives of a water mist system shall be described using the following three terms:

(a) Control;

(b) Suppression; and

(c) Extinguishment.

5-1.1.1 Fire Control. Fire control can be measured using three basic approaches:

(a) A reduction in the thermal exposure to the structure, where the primary objective is to maintain the structural integrity of the building (e.g., prevent flashover);

(b) A reduction in the threat to occupants, where the primary objective is to minimize the loss of life; and

(c) A reduction in a fire-related characteristic, such as heat release rate, fire growth rate, or spread to adjacent objects.

5-1.1.2 Fire Suppression. Fire suppression is the sharp reduction in the heat release rate of a fire and the prevention of its regrowth by a sufficient application of water mist.

5-1.1.3 Fire Extinguishment. Fire extinguishment is the complete suppression of a fire until there are no burning combustibles.

5-2 Application Parameters. Design considerations shall address both compartment variables and fire hazard classification.

5-2.1 Compartment Variables. Compartment variables shall include both the geometry of the compartment and the ventilation conditions in the compartment.

5-2.1.1 Compartment Geometry. The compartment geometry (floor area, compartment volume, ceiling height, and aspect ratio) shall be considered when designing such parameters as nozzle locations, system flow rate, and total water use needs of the system.

5-2.1.2 Ventilation. Ventilation considerations shall include both natural and forced ventilation parameters.

5-2.1.2.1* Natural Ventilation. The number, size, and location of the openings in the space (e.g., door, windows) shall be addressed in the design and installation of the system. In some cases, special precautions are necessary to minimize the effects of these openings. These precautions include, but are not limited to, automatic door closures and water mist curtains.

5-2.1.2.2 Forced Ventilation. The magnitude of the forced ventilation in the compartment shall be addressed in the design and installation of the water mist system. In some cases, consideration shall be given to shutting down the forced ventilation prior to mist system activation.

5-2.2 Fire Hazard Classification. The fire hazard shall be classified by both the combustible loading and fuel type.

5-2.2.1 Combustible Loading. A fire hazard analysis shall be conducted to determine both the design parameters of the water mist system and the type of detection/activation scheme employed by the system. The system shall be based on the fuel type, combustible loading, and anticipated fire growth rate as well as the desired fire-fighting performance objectives.

5-2.2.2 Fuel Type. Overall fire hazard is directly related to the type and quantity of the fuel present in a space. The ease of ignition/reignition of the fuel, the fire growth rate, and the difficulty of achieving control, suppression, extinguishment, or any combination thereof, shall be considered when selecting or designing a water mist system.

5-2.2.2.1 Class A Fires. Fuel loading and configuration shall be considered when selecting/designing a system to protect a space or area containing Class A materials. If fire extinguishment is desired, consideration shall be given to the potential for deep-seated fires as well as to the potential for smoldering fires.

5-2.2.2.2 Class B Fires. The hazard associated with Class B fires is related primarily to the fuel loading, fuel configuration, flashpoint, and burning rate of the fuel. Preburn time also affects the overall characteristics of the fire. Class B fires are grouped into two categories: two-dimensional pool fires and three-dimensional spray and running fuel fires. The parameters associated with each category are as follows:

(a) Class B two-dimensional fires:

1. Fuel loading and configuration;
2. Fuel flashpoint; and
3. Preburn time pool/spill size.

(b) Class B three-dimensional fires:

1. Fuel loading and configuration;
2. Fuel flashpoint;

3. Preburn time;

4. Cascade/running fuel fires;

5. Fuel flow rate;

6. Fire configuration;

7. Spray fires;

8. Fuel line pressure;

9. Fuel spray angle;

10. Fuel spray orientation; and

11. Reignition sources.

When designing and installing water mist systems to protect Class B hazards, the parameters specified in 5-2.2.2.2(a) and (b) shall be considered.

5-2.2.2.3 Class C Fires. Electrical conductivity of water and water mist shall be addressed when considering applications where the primary fire is a Class C fire.

5-2.2.2.4 Combination Fires. Combinations in fuel loadings and hazards shall be addressed.

5-2.3 Fire Location.

The location of the fuel in the space shall be considered when selecting/designing a water mist system. Some of the locations of concern include:

(a) Fuel located at higher elevations in the space;

(b) Fuel located in close proximity to vent openings;

(c) Fuel located in the corners of the space; and

(d) Fuel stacked against walls.

5-2.4 Obstructions and Shielding.

Water mist nozzles shall be positioned to distribute mist to all locations in the area or around the object being protected. The presence of obstructions and the potential for shielding of misting spray patterns shall be evaluated to ensure that the system performance is not affected.

5-3 Listing Testing.

Tests shall be conducted as part of the nozzle or system listing to address the compartment geometry, fire hazard, and performance objectives of the application specified in the listing.

5-3.1 Applicability.

Tests shall be designed to replicate most or all of the application parameters associated with a given installation. Any variations in these parameters shall be substituted using the worst case conditions. The listing of the system hardware shall be consistent with the intended system application.

5-3.2 Adequacy of Testing.

Tests shall be designed and conducted to stress the system in order to determine the working limits and parameters of the system and to incorporate adequate severity to minimize the effects of test parameter variations.

5-3.3* Results.

The results documented in the listing testing shall identify the working limits and parameters of the system, the fire hazard, and the range of compartment parameters.

Chapter 6 Calculations

6-1 General.

System flow calculation procedures for water mist systems shall be in accordance with Section 6-2.

Exception No. 1: Hydraulic calculations for systems with no additives and with working pressures not exceeding 175 psi (12 bars) shall be permitted to be performed using the method provided in Section 6-3.

Exception No. 2: Calculations for piping carrying atomizing media in twin fluid systems shall be performed in accordance with Section 6-4.

6-1.1*

Where any modification is made that alters the system flow characteristics of an existing, engineered water mist system, system flow calculations shall be furnished indicating the previous design, volume, and pressure at points of connection, and adequate calculations also shall be provided to indicate the effect on existing systems.

6-1.2

Pre-engineered systems shall not be modified outside the limits of the listing.

6-2* Darcy-Weisbach Calculation Method for Intermediate and High Pressure, Single Fluid, Single Liquid Phase Systems.

6-2.1

Pipe friction losses shall be determined using the formulae in Table 6-2.1.

Table 6-2.1. Darcy-Weisbach and Associated Equations for Pressure Loss in Intermediate and High Pressure Systems.

English Units	SI Units
Darcy-Weisbach Equation:	
$\Delta p = 0.000216 \frac{fL\rho Q^2}{d^5}$	$\Delta p_m = 2.252 \frac{fL\rho Q^2}{d^5}$
Reynolds Number:	

$$Re = 506\frac{Q\rho}{d\mu}$$

$$Re = 21.22\frac{Q\rho}{d\mu}$$

Relative roughness:

$$\text{relative roughness} = \frac{\varepsilon}{D}$$

$$\text{relative roughness} = \frac{\varepsilon}{d}$$

Δp = friction loss, psi gauge
L = length of pipe, ft
f = friction factor, psi/ft
Q = flow, gpm
d = internal pipe diameter, in.
D = internal pipe diameter, ft
ε = pipe wall roughness, ft
ρ = weight density of fluid, lb/ft^3
μ = absolute (dynamic) viscosity, in centipoise (cP)

Δp_m = friction loss, bars gauge
L = length of pipe, m
f = friction factor, bars/m
Q = flow, L/min
d = internal pipe diameter, mm
ε = pipe wall roughness, mm
ρ = weight density of fluid, kg/m^3
μ = absolute (dynamic) viscosity, in centipoise (cP)

6-2.2

Figure 6-2.2 (Moody Diagram) shall be used to determine the value of the friction factor, f, in the Darcy-Weisbach equation, where the Reynolds number and relative roughness are calculated as shown in Table 6-2.1, using coefficients provided in Tables 6-2.2(a) and 6-2.2(b).

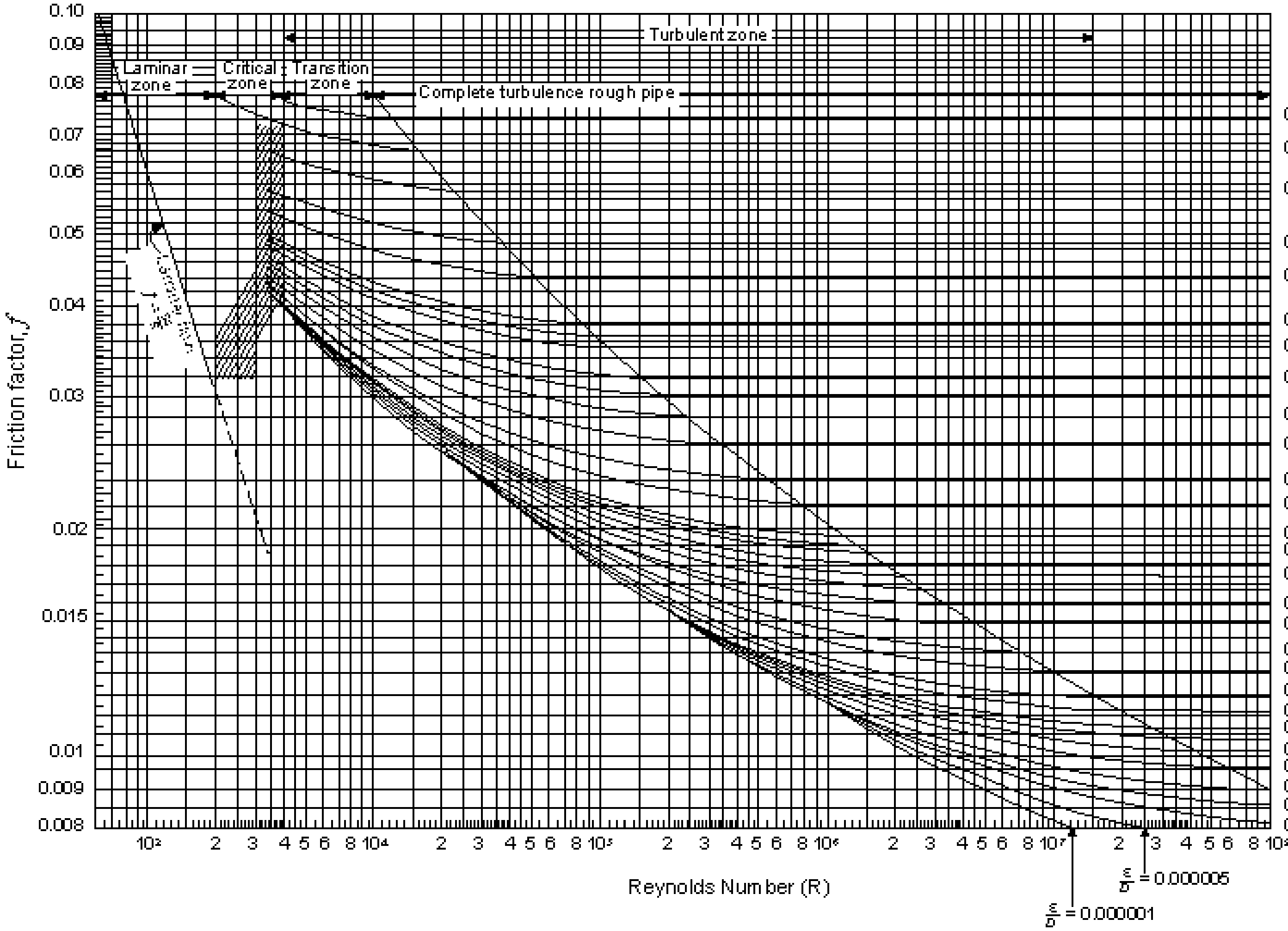


Figure 6-2.2 Moody diagram.

Table 6-2.2(a) Recommended Values of Absolute Roughness or Effective Height of Pipe Wall Irregularities, for Use in Darcy-Weisbach Equation

	Design Value of ε,	
Pipe Material (New)	**(ft)**	**(mm)**
Copper, copper nickel, drawn tubing	0.000 005	0.0015
Stainless steel	0.000 15	0.045

Table 6-2.2(b) Approximate Values of μ, Absolute (Dynamic) Viscosity, and ρ for Clean Water, over the Temperature Range 40°F to 100°F (4.4°C to 37.8°C)

Temperature °F	Temperature °C	Weight Density of Water, lb/ft^3	Weight Density of Water, kg/m^3	Absolute (Dynamic) Viscosity, μ, in Centipoise
40	4.4	62.42	999.9	1.5
50	10.0	62.38	999.7	1.3
60	15.6	62.34	998.8	1.1
70	21.1	62.27	998.0	0.95
80	26.7	62.19	996.6	0.85
90	32.2	62.11	995.4	0.74
100	37.8	62.00	993.6	0.66

6-2.3

Minimum and maximum operating pressure at each nozzle shall be within the listed operating range.

6-2.4

System piping shall be hydraulically designed to deliver the water flow requirements in accordance with the manufacturer's listing and the provisions of Chapter 5.

6-3* Hazen-Williams Calculation Method (Low Pressure Systems).

6-3.1

Hydraulic calculations for water mist systems with working pressures not exceeding 175 psi (12 bars) shall be permitted to be performed using the Hazen-Williams calculation method.

6-3.2 Friction Loss Formula.

Friction losses for water-filled pipe shall be determined on the basis of the Hazen-Williams

$$P_f = \frac{4.52 Q^{1.85}}{C^{1.85} d^{4.87}}$$

where:

P_f = Frictional resistance (psi/ft of pipe)

Q = Flow (gpm)

d = Actual internal diameter of pipe (in.)

C = Friction loss coefficient.

For SI units:

$$P_m = 6.05 \frac{Q_m^{1.85}}{C^{1.85} d_m^{4.87}} \times 10^5$$

where:

P_m = Frictional resistance (bars/m of pipe)

Q_m = Flow (L/min)

d_m = Actual internal diameter of pipe (mm)

C = Friction loss coefficient.

6-3.3 Velocity Pressure Formula.

Velocity pressure for water-filled pipe shall be determined on the basis of the following formula:

$$P_V = \frac{0.001123\, Q^2}{D^4}$$

where:

P_v = Velocity pressure (psi)

Q = Flow (gpm)

D = Inside diameter (in.).

For SI units:

$$P_V = 5.61(10)^{-7} \frac{Q^2}{D^4}$$

where:

P_v = Velocity pressure (bars)

Q = Flow (L/min)

D = Inside diameter (mm).

6-3.4 Normal Pressure Formula.

Normal pressure, P_n, shall be determined on the basis of the following formula:

$$P_n = P_t - P_v$$

where:

P_n = Normal pressure

P_t = Total pressure [psi (bars)]

P_v = Velocity pressure [psi (bars)].

6-3.5 Hydraulic Junction Points.

Pressures at hydraulic junction points shall balance within 0.5 psi (0.03 bar). The highest pressure at the junction point, and the total flows as adjusted, shall be used in the calculations.

6-3.6 Equivalent Pipe Lengths of Valves and Fittings.

6-3.6.1 Table 6-3.6.1 shall be used to determine the equivalent length of pipe for fittings and devices, unless the manufacturer's test data indicate that other factors are appropriate. For saddle-type fittings having friction loss greater than that shown in Table 6-3.6.1, the increased friction loss shall be included in hydraulic calculations. For internal pipe diameters that differ from copper tubing, the equivalent feet shown in Table 6-3.6.1 shall be multiplied by a factor derived from the following formula:

$$\left[\text{Actual inside diameter}/\text{Type K copper tube I.D.}\right]^{4.87} = \text{Factor}$$

The factor thus obtained shall be modified further in accordance with Table 6-3.6.2.

Table 6-3.6.1 Equivalent Length of Pipe for Copper Fittings and Values

Nominal or Standard Size		Fittings: Standard Ell 90°		Standard Ell 45°		90° Tee Side Branch		90° Tee Straight Run		Coupling		Valves: Ball		Gate	
(in.)	(mm)	(ft)	(m)	(ft)	(m)	(ft)	(m)	(ft)	(m)	(ft)	(m)	(ft)	(m)	(ft)	(m)
3/8	9.53	0.5	0.15			1.5	0.46								
1/2	12.7	1	0.31	0.5	0.15	2	0.61								
5/8	15.88	1.5	0.46	0.5	0.15	2	0.61								
3/4	19.05	2	0.61	0.5	0.15	3	0.91								
1	25.4	2.5	0.76	1	0.31	4.5	1.37					0.5	0.15		
1 1/4	31.75	3	0.91	1	0.31	5.5	1.68	0.5	0.15	0.5	0.15	0.5	0.15		
1 1/2	38.1	4	1.22	1.5	0.46	7	2.13	0.5	0.15	0.5	0.15	0.5	0.15		
2	50.8	5.5	1.68	2	0.61	9	2.74	0.5	0.15	0.5	0.15	0.5	0.15	0.5	0.15
2 1/2	63.5	7	2.13	2.5	0.76	12	3.66	0.5	0.15	0.5	0.15			1	0.31
3	76.2	9	2.74	3.5	1.07	15	4.57	1	0.31	1	0.31			1.5	0.46
3 1/2	88.9	9	2.74	3.5	1.07	14	4.27	1	0.31	1	0.31			2	0.61
4	101.6	12.5	3.81	5	1.52	21	6.40	1	0.31	1	0.31			2	0.61

NOTES: Allowances are for streamlined, soldered fittings and recessed threaded fittings. For threaded fittings, double the allowances shown. The equivalent lengths presented above are based upon a C factor of 150 in the Hazen-Williams friction loss formula. The lengths shown are rounded to the nearest half foot.

6-3.6.2 Table 6-3.6.1 shall be used with Hazen-Williams only where C=150. For other values of C, the values in Table 6-3.6.1 shall be multiplied by the factors in Table 6-3.6.2.

Table 6-3.6.2 C Value Multiplier

Value of C	100	120	130	140
Multiplying Factor	0.472	0.662	0.767	0.880

NOTE: The multiplying factor is based upon the friction loss through the fitting being independent of the C factor available to the piping.

6-3.6.3 Specific friction loss values or equivalent pipe lengths for special valves, strainers, and other devices shall be made available to the authority having jurisdiction.

6-3.6.4 Pipe friction loss shall be calculated in accordance with the Hazen-Williams formula C values from Table 6-3.6.4.

Table 6-3.6.4 Hazen-Williams C Values

Pipe or Tube	C Value[1]
Plastic (listed per 2-3.2 or 2-3.4.2) all types	150
Copper tube or stainless steel	150

[1]The authority having jurisdiction is permitted to consider other C values.

6-4 Pneumatic Calculation Procedures for Atomizing Media in Twin Fluid Systems.

6-4.1

Calculations shall be performed to determine the maximum and minimum pneumatic pressures and flow rates (at standard temperature and pressure) at the atomizing media inlet of each twin-fluid nozzle in multi-nozzle system. Maximum and minimum pressures at each nozzle shall be within the performance tolerances for the nozzle, as provided by the nozzle manufacturer. The following iterative procedure is described as one approach.

6-4.2

A pneumatic calculation procedure shall be based on standard engineering methods for sizing of compressed air piping systems. Air flow at each nozzle is dependent on water pressure at the same nozzle. To start the calculation, the air pressure and air flow rate at the hydraulically most remote nozzle shall be set at the optimum air pressure and flow rate for the corresponding water pressure and water flow rate at that nozzle.

6-4.3

The initial water pressure condition at the most remote nozzle shall be taken from hydraulic calculations performed independently (i.e., treating the water piping as a single fluid system), using assumed nozzle discharges. Once the water pressure and flow rate at each nozzle are determined, the corresponding required air pressure and flow rate to allow the assumed water flow rate can be estimated from information provided by the nozzle manufacturer.

6-4.4

Having determined the nominal air pressure and flow requirements at each nozzle, the pneumatic piping system shall be calculated independently, to verify that the pipe sizes are adequate to provide the required pressure and flow at each nozzle location. Using the calculated pressures at each nozzle, the effect on the water discharge rate must be checked. If the water flow rate at the calculated air pressure is within 10 percent of the assumed flow rate in 6-4.3, no correction is required. If not, the nozzle discharge shall be adjusted, and the hydraulic calculation of 6-4.3 shall be repeated. This procedure is iterative, and must be repeated until calculated air and water pressures are within the desired range and ratio.

6-4.5

The ratio of the air pressure to water pressure at each nozzle shall be maintained within 10 percent of the manufacturer's recommended operating ratio as provided by the nozzle manufacturer.

6-4.6

The results of the hydraulic and pneumatic calculations shall indicate the total water demand as a flow rate and pressure at the system supply point, and the total air flow rate (in SCFM) and initial air pressure at the atomizing media supply point.

Chapter 7 Water Supplies and Atomizing Media

7-1 General.

Unless otherwise specified, the following requirements shall apply to the water supplies, the atomizing media, and any additives necessary for fire-extinguishing performance.

7-1.1

Every water mist system shall have at least one automatic water supply.

7-1.2*

Compressed gas or other atomizing medium, where used as part of a twin fluid water mist system, shall be automatically supplied in concurrence with the water.

7-2* Quantity.

The quantities of water, water additives in listed concentrations (if used), and of atomizing media (if used) shall be at least sufficient for the largest single hazard or group of hazards to be protected simultaneously.

7-3* Duration.

Automatic supplies of water and of atomizing media (if used) shall be adequate to supply the system for a minimum of 30 minutes.

Exception No. 1: For pre-engineered systems, the minimum duration shall be sufficient for two complete discharges, as required by the listing and by Chapter 5.

Exception No. 2: Where the hazard has been evaluated by a fire protection engineer using standard methods of fire hazard analysis, the water supply duration shall be determined by the specified performance characteristics of the water mist system. It shall be permitted for this method to result in water supply duration requirements greater than or less than those specified in Section 7-3.

7-4 Reserve Supplies.

7-4.1*

A reserve supply shall be provided where the extinguishing agent cannot otherwise be replaced within 24 hours following system operation.

7-4.2

Where a reserve supply is provided, it shall be connected to the system piping at all times. If a manual changeover is necessary, the mechanism shall be readily accessible from outside of the protected space.

7-4.3

Means shall be provided to prevent discharge of reserve supplies from open manifold connections when supplies are removed for servicing.

7-5 Water Supplies.

7-5.1* Water Quality.

7-5.1.1 The water supply for a water mist system shall be taken from a source that is equivalent in quality to a potable source with respect to particulate and dissolved solids, or from a source of natural seawater.

Exception No. 1: In areas which are normally occupied, liquid or dissolved chemicals are permitted to be added to the water supplies in accordance with the listing, provided they are used at concentrations for which the manufacturer can demonstrate to the satisfaction of the U.S. Environmental Protection Agency that no adverse toxilogical or physiological effects have been observed.

Exception No. 2: For systems which protect normally unoccupied areas, liquid or dissolved chemicals are permitted to be added to the water supplies in accordance with the listing.

7-5.1.2 A filter or strainer shall be provided at the supply side of each nozzle.

Exception: Nozzles with multiple orifices and with minimum waterway dimensions greater than 800 µm per opening shall not be required to be provided with a strainer or filter at each nozzle.

7-5.1.3 A filter or a strainer shall be provided at each water supply connection or system riser. The filter or strainer shall be installed downstream (on the system side) of all piping that is not corrosion resistant. Such strainers shall be provided with a cleanout port and shall be arranged to facilitate inspection, maintenance, and replacement.

7-5.1.4 The maximum filter rating or strainer mesh opening shall be 80 percent of the minimum nozzle waterway dimension.

7-5.1.5 Systems which utilize nozzles with a minimum nozzle waterway dimension less than 51 µm shall be supplied with de-mineralized water.

7-5.2 Pumps.

7-5.2.1 Centrifugal pumps shall be sized to supply the greatest demand at not more than 140 percent of rated flow capacity.

7-5.2.2 Other pumps shall be sized to supply 110 percent of system demand at the design pressure.

7-5.2.3 Pumps supplying water mist systems shall be automatically controlled and shall be of sufficient capacity to meet the system demand.

7-5.2.4 Supervision. Pumps supplying water mist systems shall be supervised for the conditions specified in 7-5.2.4.1 and 7-5.2.4.2.

7-5.2.4.1 Electric Pumps.

(a) Pump running;

(b) Loss of power; and

(c) Phase reversal.

7-5.2.4.2 Diesel-Driven Pumps.

(a) Pump running;

(b) Power failure;

(c) Controller not in automatic position;

(d) Low oil pressure;

(e) High water temperature;

(f) Failure to start/overcrank;

(g) Overspeed; and

(h) Fuel level (set at 75 percent capacity).

7-5.3 Tanks.

7-5.3.1 Water tanks shall be arranged in accordance with NFPA 22, *Standard for Water Tanks for Private Fire Protection*.

7-5.3.2 Water tanks shall be supervised for the following conditions:

(a) Water level;

(b) Water temperature (for tanks located in unheated areas); and

(c) Air pressure (for pressure tanks).

7-5.4 Storage Containers.

7-5.4.1 Storage containers and accessories shall be located and arranged to facilitate inspection, testing, recharging, and other maintenance. Interruption to protection shall be held to a minimum.

7-5.4.2 Storage containers shall not be located where they are likely to be subject to severe weather conditions or to mechanical, chemical, or other damage.

7-5.4.3 Where excessive climatic or mechanical exposures are expected, suitable safeguards or enclosures shall be provided.

7-5.4.4 Storage containers shall be mounted securely in accordance with the manufacturer's installation manual. This shall include mounting the container on the appropriate mounting surface.

7-5.4.5 Each pressurized container or cylinder shall be provided with a safety device to release excess pressure.

7-5.4.6 A reliable means shall be provided to indicate the pressure and level in all storage containers.

7-5.5* Fire Department Connection.

A fire department connection shall be provided on the discharge side of the pressure source components. The connection to the system shall be made on the upstream (supply) side of the system strainer or filter.

Exception No. 1: For systems with operating pressures in excess of 175 psi (12 bars), the connection shall be made on the suction side of the pressure source components.

Exception No. 2: Fire department connections shall not be required for systems protecting less than 2000 ft^2 *(200* m^2*).*

Exception No. 3: Fire department connections shall not be required for systems with operating pressures in excess of 175 psi (12 bars) and supplied only by storage cylinders.

Exception No. 4: Fire department connections shall not be required for systems where the atomizing medium is essential for fire suppression.

7-6 Atomizing Media for Twin Fluid Systems.

7-6.1 General.

7-6.1.1 Atomizing media essential to the production of water mist shall be taken from a dedicated source.

Exception: Where the facility has an air supply that meets or exceeds the requirements of a dedicated main and reserve air supply, both meeting the quality, quantity, pressure, and reliability requirements of the listing and the approval of the authority having jurisdiction. Plant air used as an atomizing medium for a water mist system shall be monitored by the fire control panel, with the low air alarm set at a point at least 50 percent above the availability of two full system discharge requirements.

7-6.1.2 Atomizing media shall be supervised for high and low pressure.

7-6.1.3 Moisture content in the atomizing medium shall not exceed 25 ppm.

7-6.1.4 Regulators controlling the supply of water for the atomizing medium shall be listed for the intended purpose.

7-6.1.5 A check valve or other means shall be installed in the piping at the supply point to prevent the entrance of water into the atomizing medium.

7-6.1.6 Filters or other means to protect nozzles from obstructions shall be provided in accordance with 7-5.1.2.

7-6.2 Air Compressors.

7-6.2.1 Air compressors used as a dedicated source shall be listed for use on fire protection systems.

7-6.2.2 Compressors used as a dedicated supply shall be connected to a backup power supply.

7-7 Pressure Gauges.

A pressure gauge shall be provided for each water supply and each atomizing medium.

Chapter 8 Plans and Documentation

8-1 Working Plans.

8-1.1

Working plans shall be submitted for approval to the authority having jurisdiction before any equipment is installed or remodeled. Deviation from approved plans shall require permission of the authority having jurisdiction.

8-1.2

Working plans shall be drawn to specified scale on sheets of uniform size. Special symbols shall be defined and used to identify components of the water mist system clearly. The plans shall provide the following information that pertains to the design of the system:

(a) Name of owner and occupant;

(b) Location, including street address;

(c) Point of compass and symbol legend;

(d) Location and construction of protected enclosure walls and partitions;

(e) Location of fire walls;

(f) Enclosure cross section, with full height or schematic diagram, including location and construction of building floor/ceiling assemblies above and below, raised access floor, and suspended ceiling;

(g) Description of occupancies and hazards being protected, designating whether or not the enclosure is normally occupied;

(h) Description of exposures surrounding the enclosure;

(i) Description of water and gas storage containers used including make, internal volume, storage pressure, and nominal capacity expressed in units of mass or volume at standard conditions of temperature and pressure;

(j) Description of nozzles used including manufacturer, size, orifice port configuration, and orifice size or part number;

(k) Description of pipe and fittings used including material specifications, grade, and pressure rating;

(l) Description of wire or cable used including classification, gauge (AWG), shielding, number of strands in conductor, conductor material, and color coding schedule. The segregation requirements of various system conductors shall be clearly indicated. The required method of making wire terminations shall be detailed;

(m) Description of the method of detector mounting;

(n) Equipment schedule or bill of materials for each piece of equipment or device indicating device name, manufacturer, model or part number, quantity, and description;

(o) Plan view of the protected area showing enclosure partitions (full and partial height); water distribution system including storage containers or pumps; gas distribution system including gas storage containers; piping; nozzles; type of pipe hangers and rigid pipe supports; detection, alarm, and control system including all devices; end-of-line device locations; location of controlled devices such as dampers and shutters; and location of instructional signage;

(p) Isometric view of the water mist distribution system showing the length and diameter of each pipe segment; node reference numbers relating to the flow calculations; fittings including reducers and strainers; orientation of tees; and nozzles including size, orifice port configuration, and flow rate;

(q) Seismic building joints, if any, showing where water mist distribution or supply piping crosses the joint; expected movement of the seismic joint; details of the piping arrangement; and flexible connectors used to accommodate seismic movement;

(r) The calculation of seismic loads if seismic restraint is required by the authority having jurisdiction;

(s) Scale drawing showing the layout of the annunciator panel graphics if required by the authority having jurisdiction;

(t) Details of each unique rigid pipe support configuration showing method of securement to the pipe and to the structure;

(u) Details of the method of container securement showing method of securement to the container and to the structure;

(v) Complete step-by-step description of the system sequence of operations including functioning of abort and maintenance switches, delay timers, and emergency power shutdown;

(w) Schematic diagrams and point-to-point wiring diagrams showing all circuit connections to the system control panels, detectors, system devices, controlled devices, external and add-on relays, and graphic annunciator panels;

(x) Schematic diagrams and point-to-point wiring diagrams of the system control panels;

(y) Complete calculations to determine enclosure volume for the application of water mist; and

(z) Complete calculations to determine the size of backup batteries; the method used to determine the number and location of audible and visual indicating devices; and number and location of detectors.

8-2 Hydraulic Calculation Documentation.

8-2.1

Hydraulic calculations shall be prepared on form sheets that include a summary sheet, detailed work sheets, and a graph sheet.

Exception: Pre-engineered systems.

8-2.2 Summary Sheet.

The summary sheet shall contain the following information:

(a) Date;

(b) Location;

(c) Name of owner and occupant;

(d) Building number or other identification;

(e) Description of hazard;

(f) Name and address of contractor or designer;

(g) Name of approving agency;

(h) System design requirements, including:

1. Design area of water application or volume of space protected;
2. Minimum rate of water application (density); and
3. Area per nozzle.

(i) Total water requirements as calculated; and

(j) Limitations (dimension, flow, and pressure) resulting from the use of automatic sprinkler systems or other water fire suppression systems.

8-2.3 Detailed Work Sheets.

The detailed work sheets or computer printouts shall contain the following information:

(a) Sheet number;

(b) Nozzle description;

(c) Hydraulic reference points;

(d) Flow in gpm (L/min);

(e) Pipe size;

(f) Pipe lengths, center to center of fittings;

(g) Equivalent pipe lengths for fittings and devices;

(h) Friction loss in psi/ft (bars/m) of pipe;

(i) Total friction loss between reference points;

(j) Elevation head in psi (bars) between reference points;

(k) Required pressure in psi (bars) at each reference point;

(l) Velocity pressure and normal pressure if included in calculations;

(m) System flushing locations;

(n) Notes to indicate starting points, reference other sheets, or clarify data shown;

(o) Diagram to accompany gridded system calculations to indicate flow quantities and directions for lines with water mist nozzles operating in the remote area; and

(p) Other calculations necessary for design of the water mist system.

8-2.4 Graph Sheet.

A graphic representation of the complete hydraulic calculation shall be plotted on semilogarithmic ($Q^{1.85}$) graph paper and shall include the following:

(a) Water supply curve; and

(b) Water mist system demand.

8-3 Pneumatic Calculation Documentation.

8-3.1

Pneumatic calculations shall be prepared on form sheets that include a summary sheet and detailed work sheets.

Exception: Pre-engineered systems.

8-3.2 Summary Sheet.

The summary sheet shall contain the following information:

(a) Date;

(b) Location;

(c) Name of owner and occupant;

(d) Building number or other identification;

(e) Description of hazard;

(f) Name and address of contractor or designer; and

(g) Total gas volume required.

8-3.3 Detailed Work Sheets (for pneumatic calculations).

The detailed work sheets or computer printouts shall contain the following information:

(a) Sheet number;

(b) Nozzle description;

(c) Pneumatic reference points;

(d) Atomizing media flow rate (in SCFM) and pressure at each nozzle;

(e) The air pressure to water pressure ratio at each nozzle;

(f) Pipe size;

(g) Pipe lengths;

(h) Total pressure loss between reference points;

(i) Required pressure in psi (bars) at each reference point; and

(j) Notes to indicate starting points, reference other sheets, or clarify data shown.

8-4 Detection, Actuation, and Control Systems Documentation.

After successful completion of acceptance tests satisfactory to the authority having jurisdiction, as-built installation documentation shall be prepared and provided to the system owner or the owner's designated representative, including as-built installation drawings, operation and maintenance manuals, a written sequence of operation, and reports.

8-4.1 As-Built Installation Drawings.

A set of as-built installation drawings, reproducible and drawn to a scale specified on sheets of uniform size, shall provide the as-built configuration of detection, actuation, and control systems and shall include:

(a) The name of owner and occupant;

(b) The location, including street address;

(c) The plan view of the protected area showing all detector locations; end-of-line device locations; location of detector indicating lights if separate from the detectors; location of audible and visual indicating devices; location of control panels; location of manual release and abort switches; location of controlled devices such as dampers and shutters; location of maintenance and emergency power shutdown switches; and location of the annunciator panel;

(d) An equipment schedule or bill of materials for each piece of equipment or device indicating the device name, manufacturer, model or part number, quantity, and description;

(e) A description of wire or cable used including classification, gauge (AWG), shielding, number of strands in conductor, conductor material, and color coding schedule. The segregation requirements of various system conductors shall be clearly indicated. The as-built method of making wire terminations shall be detailed;

(f) A scale drawing showing the graphics layout of all annunciator panels;

(g) Schematic diagrams and point-to-point wiring diagrams showing all circuit connections to the system control panels, detectors, system devices, controlled devices, external and add-on relays, and graphic annunciator panels;

(h) Schematic diagrams and point-to-point wiring diagrams of the system control panels;

(i) The size and type of backup batteries; and

(j) The details of any special features.

8-4.2 Operation and Maintenance Manuals.

Operation and maintenance manuals shall include operation and maintenance instructions for each piece of equipment or device of the as-built system.

8-4.3 Written Sequence of Operation.

The written sequence of operation of the as-built system shall include a complete step-by-step description of the functioning of abort and maintenance switches, delay timers, and emergency power shutdown features.

8-4.4 Reports.

Reports shall include inspection, testing, and maintenance reports.

Chapter 9 System Acceptance

9-1 Approval of Water Mist Systems.

The completed system shall be reviewed and tested by qualified personnel to meet the approval of the authority having jurisdiction. These personnel shall confirm that listed equipment and devices have been used in the system where required by this standard. To determine that the system has been properly installed and functions as specified, the installing contractor shall:

(a) Notify the authority having jurisdiction and the owner's representative of the time and date testing is to be performed; and

(b) Perform all required acceptance tests.

9-2* Acceptance Requirements.

9-2.1 Flushing or Cleaning of Piping.

9-2.1.1 Water Supply Connection. Where systems are connected to municipal or private water supplies, underground mains and lead-in connections to water mist system piping shall be flushed completely before connection is made to water mist piping. The flushing operation shall be continued for a sufficient time to ensure thorough cleaning. The minimum rate of flow shall be one of the following, whichever is greater:

(a) The hydraulically calculated water demand rate of the system; or

(b) The maximum flow rate available to the system under fire conditions.

9-2.1.2 System Pipe or Tube. Each pipe or tube section shall be cleaned internally after preparation and before assembly in accordance with the manufacturer's installation manual. The piping network shall be free of particulate matter and oil residue before installation of nozzles or discharge devices.

9-2.2 Hydrostatic Tests.

9-2.2.1 General.

9-2.2.1.1 The test pressure shall be read from a gauge located at the low elevation point of the system or portion being tested.

9-2.2.1.2 Water used for testing shall be filtered or strained to remove all solids of a size sufficient to obstruct the water mist nozzles.

9-2.2.1.3 Additives, corrosive chemicals such as sodium silicate or derivatives of sodium silicate, brine, or other chemicals shall not be used while hydrostatically testing systems or for stopping leaks.

9-2.2.1.4 Test blanks shall have painted lugs protruding in such a way as to clearly indicate their presence. The test blanks shall be numbered, and the installing contractor shall have a recordkeeping method to ensure their removal after work is completed.

9-2.2.2 Low Pressure System. All interior piping and attached appurtenances subjected to system working pressure shall be hydrostatically tested at 200 psi (13.8 bars) and shall maintain that pressure without loss for 2 hours. Loss shall be determined by a drop in gauge pressure or visible leakage.

Exception No. 1: Portions of systems normally subjected to working pressures in excess of 150 psi (10.4 bars) shall be tested as described above at a pressure of 50 psi (3.5 bars) in excess of normal working pressure.

Exception No. 2: Where cold weather does not allow testing with water, an interim air test shall be conducted as described in 9-2.3.

9-2.2.3 Intermediate and High Pressure Systems. All interior piping and attached appurtenances subjected to system pressure shall be hydrostatically tested to 150 percent of the normal working pressure, and they shall maintain that pressure without loss for 2 hours. Loss shall be determined by a drop in gauge pressure or visible leakage.

9-2.3 Air Tests.

For dry and preaction systems, an air pressure leakage test at 40 psi (2.8 bars) shall be conducted for 24 hours in addition to the standard hydrostatic test. Any leakage that results in a loss of pressure in excess of $1^1/_2$ psi (0.1 bars) during the 24 hours shall be corrected.

> CAUTION: Pneumatic pressure testing creates a potential risk of injury to personnel in the area as a result of airborne projectiles if rupture of the piping system occurs. Prior to the pneumatic pressure test being conducted, the area shall be evacuated and appropriate safeguards shall be provided for test personnel.

9-2.4 Review of Components.

9-2.4.1 Review of Mechanical Components.

9-2.4.1.1 The piping system shall be inspected to determine that it is in compliance with the design and installation documents and hydraulic calculations.

9-2.4.1.2 Nozzles and pipe size shall be in accordance with system drawings. The means of pipe size reduction and the attitudes of tees shall be checked for conformance to the design.

9-2.4.1.3 Piping joints, discharge nozzles, and piping supports shall be fastened securely to prevent unacceptable vertical or lateral movement during discharge. Discharge nozzles shall be installed in such a manner that piping cannot become detached during discharge.

9-2.4.1.4 The discharge nozzle shall be oriented in such a manner that optimum water mist application can be effected.

9-2.4.1.5 The discharge nozzles, piping, and mounting brackets shall be installed in such a manner that they do not potentially cause injury to personnel.

9-2.4.1.6 All water and gas storage containers shall be located properly in accordance with an approved set of system drawings.

9-2.4.1.7 All containers and mounting brackets shall be fastened securely in accordance with the manufacturer's requirements.

9-2.4.2 Review of Electrical Components.

9-2.4.2.1 All wiring systems shall be checked for proper installation in conduit and in compliance with the approved drawings. It shall be confirmed that ac wiring and dc wiring are not combined in a common conduit or raceway unless properly shielded and grounded.

9-2.4.2.2 All field circuits shall be confirmed to be free of ground faults and short circuits. Where measuring field circuitry, all electronic components, such as smoke and flame detectors or special electronic equipment for other detectors or their mounting bases, shall be removed, and jumpers shall be installed properly to prevent the possibility of damage within these devices. Components shall be replaced after measuring.

9-2.4.2.3 The detection devices shall be checked for proper type and location as specified on the system drawings.

9-2.4.2.4 The detectors shall be installed in a professional manner and in accordance with technical data regarding their installation. NFPA 72, *National Fire Alarm Code*, shall be referenced for installation requirements. In Canada, CAN/ULC S524-M86, *Standard for the Installation of Fire Alarm Systems*, and CAN/ULC S529-M87, *Smoke Detectors for Fire Alarm Systems*, shall be referenced.

9-2.4.2.5 Manual pull stations shall be confirmed as readily accessible, accurately identified, and properly protected to prevent damage.

9-2.4.2.6 For systems using abort switches, the switches shall be confirmed to be of the deadman type that necessitates constant manual pressure, properly installed, readily accessible within the hazard area, and clearly identified. Switches that remain in the abort position when released shall not be permitted for this purpose. Verification that normal and manual emergency control overrides the abort function shall be made.

9-2.4.2.7 Polarity shall have been observed on all polarized alarm devices and auxiliary relays.

9-2.4.2.8 All end-of-line resistors shall have been installed across the detection and alarm bell circuits where required.

9-2.4.2.9 The control unit shall be checked for proper installation and ready accessibility.

9-2.4.2.10* All wiring systems shall be checked for proper grounding and shielding. It shall be verified that the water mist system branch piping has not been used as an electrical ground.

9-2.5 Preliminary Functional Tests.

9-2.5.1 If the system is connected to an alarm receiving office, the alarm receiving office shall be notified that the fire system test is to be conducted and that an emergency response by the fire department is not desired. All concerned personnel at the end-user's facility shall be notified that a test is to be conducted and shall be instructed as to the sequence of operation.

9-2.5.2 Each water mist release mechanism shall be disabled so that activation of the release circuit does not release water mist. The release circuit shall be reconnected with a functional device in lieu of each water mist release mechanism. For electrically actuated release mechanisms, these devices can include 24-volt lamps, flash bulbs, or circuit breakers. For pneumatically actuated release mechanisms, these devices can include pressure gauges. The manufacturer's installation manual shall be referenced for recommended procedures and test methods.

9-2.5.3 Each detector shall be checked for proper response.

9-2.5.4 All auxiliary functions such as alarm sounding or displaying devices, remote annunciators, air-handling shutdown, and power shutdown shall be checked for proper operation in accordance with system requirements and design specifications.

9-2.5.5 Manual pull stations shall be checked to confirm that they override abort switches.

9-2.5.6 All supervised circuits shall be checked for proper trouble response.

9-2.6 System Operational Tests.

9-2.6.1 Where practicable, full flow tests of the system piping using water shall be made as a means of checking the nozzle layout, discharge pattern, and any obstructions, determining the relationship between design criteria and actual performance, and ensuring against the clogging of the smaller piping and nozzles by foreign matter carried by the water.

9-2.6.2 Where practicable, the maximum number of systems that are expected to operate in case of fire shall be in full operation simultaneously when checking the adequacy and condition of the water supply.

9-2.6.3 All operating parts of the system shall be tested fully to ensure that they function as intended. It shall be verified that all devices function properly and that they are properly sequenced.

9-2.6.4 After flow testing, all filters and strainers shall be inspected, and cleaned or replaced, as necessary.

Chapter 10 System Maintenance

10-1 Responsibility of the Owner or Occupant.

10-1.1

The responsibility for properly maintaining a water mist fire protection system shall be the obligation of the property owner. By means of periodic inspection, tests, and maintenance, the equipment shall be shown to be either in good operating condition or that defects or impairments exist.

10-1.2

Inspection, testing, and maintenance activities shall be implemented in accordance with procedures meeting or exceeding those established in this document and in accordance with the manufacturer's instructions. These tasks shall be performed by personnel who have developed competence through training and experience.

10-1.3

The owner or occupant shall notify the authority having jurisdiction, the fire department (if required), and the alarm receiving facility before shutting down a system or its supply. The notification shall include the purpose for the shutdown, the system or component involved, and the estimated time needed. The authority having jurisdiction, the fire department, and the alarm receiving facility shall be notified when the system, supply, or component is returned to service.

10-1.4

The owner or occupant shall promptly correct or repair deficiencies, damaged parts, or impairments found while performing the inspection, test, and maintenance requirements of this standard. Corrections and repairs shall be performed by qualified maintenance personnel or a qualified contractor.

10-1.5

The owner or occupant shall give special attention to factors that might alter the requirements for a continued satisfactory or acceptable installation. Such factors shall include, but shall not be limited to:

(a) Occupancy changes;

(b) Process or material changes;

(c) Structural revisions such as relocated walls, added horizontal or vertical obstructions, or ventilation changes; and

(d) Removal of heating systems in spaces with piping subject to freezing.

10-1.6

Where changes in the occupancy, hazard, water supply, storage arrangement, structural modification, or other condition that affects the installation criteria of the system are identified, the owner or occupant shall promptly take steps to evaluate the adequacy of the installed system to protect the hazard in question, such as contacting a qualified contractor, consultant, or engineer. Where the evaluation reveals a deficiency, the owner shall notify the insurance underwriter, the authority having jurisdiction, and the local fire department.

10-1.7

Where a water mist system is returned to service following an impairment, it shall be verified that it is working properly. Chapter 9 shall be referenced to provide guidance on the type of inspection or test, or both, that is required.

10-2 Inspection and Testing.

All components and systems shall be inspected and tested to verify that they function as intended. The frequency of inspections and tests shall be in accordance with Tables 10-2(a) and (b) or as specified in the manufacturer's listing, whichever is more frequent. Following tests of components or portions of water mist systems that require valves to be opened or closed, the system shall be returned to service, with verification that all valves are restored to their normal operating position. Plugs or caps for auxiliary drains or test valves shall be replaced.

10-2.1

Test results shall be compared with those of the original acceptance test (if available) and with the most recent test results.

10-2.2

Inspection and testing requirements for each component are provided in Tables 10-2(a) and (b).

10-2.3

Specialized equipment required for testing shall be in accordance with the manufacturer's specifications.

Table 10-2(a) Inspection Frequencies

Item	Activity	Frequency
Water tank (unsupervised)	Check water level	Weekly
Air receiver (unsupervised)	Check air pressure	Weekly
Dedicated air compressor (unsupervised)	Check air pressure	Weekly
Water tank (supervised)	Check water level	Monthly
Air receiver (supervised)	Check air pressure	Monthly
Dedicated air compressor (supervised)	Check air pressure	Monthly
Air pressure cylinders (unsupervised)	Check pressure and indicator disk	Monthly
System operating components, including control valves (locked/unsupervised)	Inspect	Monthly
Air pressure cylinders (supervised)	Check pressure and indicator disk	Quarterly
System operating components, including control valves	Inspect	Quarterly
Waterflow alarm and supervisory devices	Inspect	Quarterly
Initiating devices and detectors	Inspect	Semiannually
Batteries, control panel, interface equipment	Inspect	Semiannually
System strainers and filters	Inspect	Annually
Control equipment, fiber optic cable connections	Inspect	Annually
Piping, fittings, hangers, nozzles, flexible tubing	Inspect	Annually

Table 10-2(b) Testing Frequencies

Item	Activity	Frequency
Pumps	Operation test (no flow)	Weekly
Compressor (dedicated)	Start	Monthly
Control equipment (functions, fuses, interfaces, primary power, remote alarm) (unsupervised)	Test	Quarterly
System main drain	Drain test	Quarterly
Remote alarm annunciation	Test	Annually
Pumps	Function test (full flow)	Annually
Batteries	Test	Semiannually
Pressure relief valve	Manually operate	Semiannually
Control equipment (functions, fuses, interfaces, primary power, remote alarm) (supervised)	Test	Annually
Water level switch	Test	Annually
Detectors (other than single use or self-testing)	Test	Annually
Release mechanisms (manual and automatic)	Test	Annually
Control unit/programmable logic control	Test	Annually
Section valve	Function test	Annually
Water	Analysis of contents	Annually
Pressure cylinders (normally at atmospheric pressure)	Pressurize cylinder (discharge if possible)	Annually
System	Flow test	Annually
Pressure cylinders	Hydrostatic test	5-12 years
Automatic nozzles	Test (random sample)	20 years

10-2.4

High pressure cylinders used in water mist systems shall not be recharged without a hydrostatic test (and remarking) if more than 5 years have elapsed from the date of the last test. Cylinders that have been in continuous service without discharging shall be permitted to be retained in service for a maximum of 12 years, after which they shall be discharged and retested before being returned to service.

10-3 Maintenance.

10-3.1

Maintenance shall be performed to keep the system equipment operable or to make repairs. As-built system installation drawings, original acceptance test records, and device manufacturer's maintenance bulletins shall be retained to assist in the proper care of the system and its components.

10-3.2

Preventive maintenance includes, but is not limited to, lubricating control valve stems, adjusting packing glands on valves and pumps, bleeding moisture and condensation from air compressors and air lines, and cleaning strainers. Scheduled maintenance shall be performed as outlined in Table 10-3.2.

Table 10-3.2 Maintenance Frequencies

Item	Activity	Frequency
Water tank	Drain and refill	Annually
System	Flushing	Annually
Strainers and filters	Clean or replace as required	After system operation

10-3.3

Corrective maintenance includes, but is not limited to, replacing loaded, corroded, or painted nozzles, replacing missing or loose pipe hangers, cleaning clogged fire pumps, replacing valve seats and gaskets, and restoring heat in areas subject to freezing temperatures where water-filled piping is installed.

10-3.4

Emergency maintenance includes, but is not limited to, repairs due to piping failures caused by freezing or impact damage, repairs to broken water mains, and replacing frozen or fused nozzles, defective electric power, or alarm and detection system wiring.

10-3.5

Specific maintenance activities, where applicable to the type of water mist system, shall be performed in accordance with the schedules in Table 10-3.2.

10-3.6

Replacement components shall be in accordance with the manufacturer's specifications and the original system design. Spare components shall be readily accessible and shall be stored in a manner to prevent damage or contamination.

10-3.7*

After each system operation, a representative sample of operated water mist nozzles in the activated zone shall be inspected.

10-3.8

After each system operation due to fire, the system filters and strainers shall be cleaned or replaced.

10-4 Training.

All persons who might be expected to inspect, test, maintain, or operate water mist systems shall be trained thoroughly in the functions they are expected to perform. Refresher training shall be provided as recommended by the manufacturer or by the authority having jurisdiction.

Chapter 11 Marine Systems

11-1 General.

This chapter outlines the deletions, modifications, and additions that are necessary for marine applications. All other requirements of NFPA 750, *Standard on Water Mist Fire Protection Systems*, shall apply to shipboard systems except as modified by this chapter.

11-1.1

The following definitions shall be applicable to this chapter.

Flammable Liquid Hazards Systems. Systems protecting spaces where the predominant hazard consists of flammable and combustible liquids. Examples include machinery spaces, flammable liquid store rooms, cargo pump rooms and paint lockers.

Sprinkler Equivalent Systems. Systems protecting spaces where the predominant hazard consists of Class A combustibles. Examples include accommodation spaces, public spaces, galleys, and store rooms.

11-1.2*

The efficacy and reliability of all marine water mist system arrangements and their components shall be tested in accordance with standards developed by the International Maritime Organization (IMO).

11-1.2.1 Sprinkler equivalent systems shall comply with the fire suppression and component manufacturing tests of IMO Assembly Resolution A.800(19).

11-1.2.2 Flammable liquid hazard systems shall comply with fire suppression and components manufacturing tests contained in IMO *Maritime Safety Committee Circular* 668, as amended by IMO FP40/WP.9 Annex 3, *Report of the 40th Session of the Subcommittee on Fire Protection.*.

11-1.3

All marine water mist systems and their components shall be listed or approved.

11-1.4

The system and equipment shall be suitably designed to withstand ambient temperature changes, vibrations, humidity, shock, impact, clogging, and corrosion normally encountered in ships.

11-1.5*

Equipment and piping systems mounting and hanging practices shall be in accordance with internationally recognized standards for marine applications.

11-1.6*

The required water mist pumps shall be arranged such that with the largest pump out of service, the greatest system demand can still be satisfied.

11-1.7 Controls and Alarms.

11-1.7.1 Pump systems shall have the following:

(a) Automatic pump start-up; and

(b) Manual pump start and annunciation at the following locations:

1. Near the pump;
2. Engine control room; and
3. Central control station where provided.

11-1.7.2 Annunciation shall include (as applicable):

(a) Power available/power failure;

(b) Water flow and location;

(c) Pump run; and

(d) Diesel driver oil pressure.

11-1.7.3 Any flow condition shall sound an alarm on the bridge or at a constantly manned control station.

11-1.7.4 On the bridge and in the engine control room there shall be a pressure monitor consisting of one of the following:

(a) Pressure gauge;

(b) Transducer system; or

(c) High/low/OK pressure switch.

11-2 Sprinkler Equivalent Systems.

11-2.1

The system shall be automatic.

11-2.2

The water mist system shall be adequate to supply the system with fresh water for a period of at least 30 minutes. The vessel's potable water supply shall be permitted to constitute an acceptable source to satisfy the 30-minute demand period.

11-2.3

A pressure tank system shall be provided to meet the functional requirements for Safety of Life at Sea (SOLAS) Regulation II-2/12.4.1.

11-2.4*

After 30 minutes of system activation, manual intervention shall be permitted for continued operation.

11-2.5

The system shall be fitted with a permanent sea inlet and be capable of continuous operation using sea water for a period of at least 120 minutes.

11-2.6

Strainers and filters shall be provided and sized for the worst case water quality conditions expected.

11-2.7*

The system shall be of the wet pipe type.

Exception: Where environmental conditions dictate, small sections are permitted to be of another approved type.

11-2.8

The system shall be provided with main and emergency sources of power.

11-2.9

Pumps and alternate supply components shall be sized to be capable of maintaining the required flow.

11-2.10

The water supply shall be sufficient to meet the flow and pressure requirements as determined by the listing of all nozzles in the hydraulically most remote design area determined in accordance with 11-2.10.1 and 11-2.10.2.

11-2.10.1 In ordinary hazard public spaces, the design area shall be 3014 ft^2 (280 m^2).

11-2.10.2 In light hazard public spaces and accommodation spaces, the design area shall be 1507 ft^2 (140 m^2).

Exception: The water supply requirements for nozzles only shall be based upon the room that creates the greatest demand. The density selected shall be in accordance with the listing. To utilize this method, all rooms shall be enclosed with walls having a fire resistance rating equivalent to an A-15 or B-15 rating.

Minimum protection of opening shall be as follows:

Light hazard. Automatic or self-closing doors.

Exception: Where opening is not protected, calculations shall include the nozzle in the room plus two nozzles in the communication space nearest each such unprotected opening unless the communication space has only one nozzle, in which case calculations shall be extended to the operation of that nozzle. The selection of the room and communication space nozzles to be calculated shall be that which produces the greatest hydraulic demand.

Ordinary and extra hazard. Automatic or self-closing doors with appropriate fire resistance ratings for the enclosure.

11-2.11

The water supply shall be sufficient to meet the total flow and pressure requirements of all nozzles in the hydraulically most remote design area determined in conformance with 11-2.11.1

and 11-2.11.2.

11-2.11.1 In ordinary hazard public spaces, the design area shall be 3014 ft^2 (280 m^2).

11-2.11.2 In light hazard public spaces and accommodation spaces, the design area shall be 1507 ft^2 (140 m^2), plus 3 nozzles in the corridor outside the compartment.

Exception: In accommodation spaces consisting of small compartments and an adjacent corridor, the design area shall include all nozzles in the largest compartment plus 3 nozzles in the corridor outside the compartment, provided that the compartment boundaries (floors, walls, ceilings) meet the following conditions:

(a) Open to the weather; or

(b) Have a fire resistance rating of not less than 15 minutes; and

(c) Doors opening into adjacent spaces or onto the corridor have a fire resistance rating of not less than 15 minutes and are equipped with automatic self-closing devices designed to close the doors on receipt of signal from the fire alarm system or upon actuation of the water mist system.

11-2.12

Spaces shall be permitted to be protected with alternate, approved fire suppression systems when such areas are separated from mist protected areas with a 1-hour rated assembly.

11-2.13

Water mist supply components shall be located outside Category A machinery spaces. This shall apply to pumps, pressure tanks, cylinder tanks, emergency power cables, and controllers.

11-3 Flammable Liquids.

11-3.1

This section applies to flammable liquid hazard systems.

11-3.2

Flammable liquid hazard systems shall be shown by test to be capable of extinguishing a variety of fires that can occur in spaces where the predominate hazard consists of flammable liquids.

11-3.2.1 Systems for machinery spaces and cargo pump rooms shall be capable of fire extinguishment as demonstrated by testing in accordance with IMO Fire Test Procedures. Systems for flammable liquid store rooms, paint lockers, and other flammable liquid hazards shall be based on tests acceptable to the authority having jurisdiction. Nozzle locations, types of nozzles, and spray characteristics shall be within the limits tested.

11-3.3*

The system shall be capable of manual actuation allowing water to discharge into the protected space without the necessity of further human intervention.

11-3.3.1* After 30 minutes of system activation, manual intervention shall be permitted for continued operation.

11-3.4*

Where time delays are provided, audible and visual signals shall be provide throughout the protected space.

11-3.5 Water Supply.

11-3.5.1 The system's water supply shall be available for immediate use.

11-3.5.2 The water supply shall be based on complete protection of the space demanding the greatest quantity of water.

11-3.5.3 Pressure tank(s) shall be provided to immediately supply the system at the design flow and pressure for not less than 60 seconds.

11-3.5.4 The water supply shall be adequate to supply the system with fresh water for a period of at least 30 minutes. The vessel's potable water supply shall be permitted to constitute an acceptable source to satisfy the 30-minute demand period.

11-3.5.4.1 The fresh water supply shall meet the water quality requirements of 7-5.1.

11-3.5.5 Where the water mist system is designed for uniform cycling, the maximum-reduced discharge period is 60 seconds.

11-3.5.6* The minimum quantity of water used in uniform cycling systems shall be the maximum system flow for a 15-minute constant duration.

11-3.5.7* The system shall be fitted with a permanent sea inlet and be capable of continuous operation using sea water.

11-3.6* Power Supplies.

The system shall be provided with both main and emergency sources of power and shall be provided with automatic change over. One of those sources of power shall be wholly provided from outside the protected space.

11-3.7

Pressure source components of the system shall be located outside the protected space.

11-3.8

A means to allow for periodic testing of the operation of the system for assuring the required pressure and flow shall be provided.

11-4* Human Factors.

Human factors shall be considered to the extent practicable during the design of water mist systems on marine vessels.

Chapter 12 Referenced Publications

12-1

The following documents or portions thereof are referenced within this standard and shall be considered part of the requirements of this document. The edition indicated for each reference is the current edition as of the date of the NFPA issuance of this document.

12-1.1 NFPA Publications.

National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.

NFPA 13, *Standard for the Installation of Sprinkler Systems*, 1996 edition.

NFPA 20, *Standard for the Installation of Centrifugal Fire Pumps*, 1996 edition.

NFPA 22, *Standard for Water Tanks for Private Fire Protection*, 1996 edition.

NFPA 70, *National Electrical Code*, 1996 edition.

NFPA 72, *National Fire Alarm Code*, 1996 edition.

12-1.2 Other Publications.

12-1.2.1 ANSI Publications. American National Standards Institute, 11 West 42nd Street, New York, NY 10036.

ANSI B1.20.1-83, *Pipe Threads, General Purpose (Inch),* 1992.

ANSI B16.18-84, *Cast Copper Alloy Solder Joint Pressure Fittings*, 1994.

ANSI B16.22-89, *Wrought Copper and Copper Alloy Solder Joint Pressure Fittings*, 1989.

ANSI B31.1-95*, Power Piping Code*, 1995.

12-1.2.2 ASME Publication. American Society of Mechanical Engineers, 345 East 47th Street, New York, NY 10017.

ASME *Boiler and Pressure Vessel Code*, 1995.

12-1.2.3 ASTM Publications. American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103.

ASTM A 269, *Standard Specification for Seamless and Welded Austenitic Stainless Steel Tubing for General Service*, 1994.

ASTM A 351/ASTM A 351M, *Standard Specification for Castings, Austenitic, Austenitic-Ferritic (Duplex) for Pressure-Containing Parts*, 1994.

ASTM A 403/ASTM A 403M, *Standard Specification for Wrought Austenitic Stainless Steel Piping Fittings*, 1995.

ASTM A 632, *Standard Specification for Seamless and Welded Austenitic Stainless Steel Tubing (Small-Diameter) for General Service*, 1990.

ASTM A 774/ASTM A 774M, *Standard Specification for As-Welded Wrought Austenitic Stainless Steel Fittings for General Corrosive Service at Low and Moderate Temperatures*, 1995.

ASTM A 778, *Standard Specification for Welded, Unannealed Austenitic Stainless Steel Tubular Products*, 1990.

ASTM A 789/ASTM A 789M, *Standard Specification for Seamless and Welded Ferritic/Austenitic Stainless Steel Tubing for General Service*, 1995.

ASTM A 815/ASTM A 815M, *Standard Specification for Wrought Ferritic, Ferritic/Austenitic, and Martensitic Stainless Steel Piping Fittings*, 1995.

ASTM B 32, *Standard Specification for Solder Metal*, 1995.

ASTM B 75, *Standard Specification for Seamless Copper Tube*, 1995.

ASTM B 88, *Standard Specification for Seamless Copper Water Tube*, 1995.

ASTM B 251, *Standard Specification for General Requirements for Wrought Seamless Copper and Copper-Alloy Tube*, 1993.

ASTM B 813, *Standard Specification for Liquid and Paste Fluxes for Soldering Applications of Copper and Copper-Alloy Tube*, 1993.

ASTM E 380, *Standard Practice for Use of the International System of Units (SI) (the Modernized Metric System)*, 1993.

12-1.2.4 AWS Publications. American Welding Society, Inc., 550 N.W. LeJeune Road, Maimi, FL 33126.

AWS A5.8, *Specification for Filler Metals for Brazing and Braze Welding*, 1992.

AWS D10.9, *Specification for Qualification of Welding Procedures and Welders for Piping and Tubing*, 1980.

12-1.2.5 CSA Publication. Canadian Standards Association, Rexdale, Ontario, Canada.

CAN3-A234.1, *Canadian Metric Practice Guide*, 1979.

12-1.2.6 IMO Publications. International Maritime Organization, 4 Albert Embankment, London, SEI 7SR, United Kingdom.

IMO A.800(19) Assembly Resolution.

IMO Fire Test Procedures.

IMO FP40/WP.9 Annex 3, Report of the 40th Session of the Subcommittee on Fire Protection.

IMO MSC Cir 668, *Maritime Safety Committee Circular*.

SOLAS Regulation 11-2/12.4.1, Consolidated Edition 1992.

12-1.2.7 ULC Publications. Underwriters Laboratories Canada, 7 Crouse Road, Scarborough, ON M1R 3A9.

CAN/ULC S524-M86, *Standard for the Installation of Fire Alarm Systems*.

CAN/ULC S529-M87, *Smoke Detectors for Fire Alarm Systems*.

12-1.2.8 U.S. Government Publication. Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20401.

Title 49, *Code of Federal Regulations*.

Appendix A Explanatory Material

This Appendix is not part of the requirements of this NFPA document but is included for informational purposes only.

A-1-1 Other NFPA standards should be referenced for additional requirements relating to underground or lead-in connections to water mist systems from municipal or private water supplies.

A-1-4.1 Approved. The National Fire Protection Association does not approve, inspect, or certify any installations, procedures, equipment, or materials; nor does it approve or evaluate testing laboratories. In determining the acceptability of installations, procedures, equipment, or materials, the authority having jurisdiction may base acceptance on compliance with NFPA or other appropriate standards. In the absence of such standards, said authority may require evidence of proper installation, procedure, or use. The authority having jurisdiction may also refer to the listings or labeling practices of an organization concerned with product evaluations that is in a position to determine compliance with appropriate standards for the current production of listed items.

A-1-4.1 Authority Having Jurisdiction. The phrase "authority having jurisdiction" is used in NFPA documents in a broad manner, since jurisdictions and approval agencies vary, as do their responsibilities. Where public safety is primary, the authority having jurisdiction may be a federal, state, local, or other regional department or individual such as a fire chief; fire marshal; chief of a fire prevention bureau, labor department, or health department; building official; electrical inspector; or others having statutory authority. For insurance purposes, an insurance inspection department, rating bureau, or other insurance company representative may be the authority having jurisdiction. In many circumstances, the property owner or his or her designated agent assumes the role of the authority having jurisdiction; at government installations, the commanding officer or departmental official may be the authority having jurisdiction.

A-1-4.1 Listed. The means for identifying listed equipment may vary for each organization concerned with product evaluation, some of which do not recognize equipment as listed unless it is also labeled. The authority having jurisdiction should utilize the system employed by the listing organization to identify a listed product.

A-1-4.1 Water Mist. This standard addresses the use of fine water sprays for the efficient control or extinguishment of fires using limited volumes of water. Properly designed water mist systems can be effective on both liquid fuel (Class B) and solid fuel (Class A) fires. Research indicates that droplets smaller than 400 microns are essential for extinguishment of Class B fires, while larger drop sizes are effective for Class A combustibles, which benefit from extinguishment by fuel wetting. For this reason the definition of water mist in this standard includes sprays with $Dv_{0.99}$ of up to 1000 microns.

This standard's definition of "water mist" includes some water sprays used in NFPA 15, *Standard for Water Spray Fixed Systems for Fire Protection*, some sprays produced by standard sprinklers operating at high pressure, as well as light mists suitable for greenhouse misting and HVAC humidification systems. This range is so broad that some important differences in the performance of sprays with finer distributions are not distinguished.

As a means of allowing distinctions to be made between "coarser" and "finer" sprays across the 1000-micron spectrum of this standard's definition of water mist, it is useful to subdivide mist into Class 1, 2, or 3 water mist, according to the drop size distribution. The defining boundaries for the three classifications are illustrated in Figure A-1-4.1.

Class 1 Water Mist. The cumulative percent volume distribution curve lies entirely to the left of a line connecting $Dv_{0.1}$ = 100 microns and $Dv_{0.9}$ = 200 microns. This represents the "finest" water mist. Many commercially available water mist nozzles produce Class 1 mists.

Class 2 Water Mist. A portion of the cumulative percent volume distribution curve lies beyond the limits of a Class 1 spray, but entirely to the left of the line connecting $Dv_{0.1}$ = 200 microns and $Dv_{0.9}$ = 400 microns. Such sprays can be generated by pressure jet nozzles, twin-fluid nozzles, and many impingement nozzles. Due to the presence of larger drops, higher mass flow rates are easier to achieve with Class 2 sprays than with Class 1 sprays. The larger drops are not too large to be effective on liquid fuel fires, however. Considerable surface wetting occurs with sprays in this range, so a Class 2 mist is also likely to be effective on fires involving ordinary combustibles.

Class 3 Water Mist. The $Dv_{0.9}$ is greater than 400 microns, or for which any portion of the curve extends to the right of the Class 2 cut-off line (but the $Dv_{0.99}$ is less than 1000 microns). Such sprays are typically generated by intermediate pressure, small orifice sprinklers, impingement nozzles of various sorts, and fire hose fog-nozzles. High mass flow rates are possible. They are suitable for Class A combustibles, and under some circumstances provide fire control or fire extinguishment for Class B fires.

The relationship between drop size distribution and extinguishing capacity of a water mist is complex. In general, Class 1 and Class 2 sprays are successful at extinguishing liquid fuel pool fires and spray fires without agitation of liquid pool surfaces. Given an appropriate geometry, Class 3 sprays are reported to have extinguished pool fires, however. Also in general, it is difficult to extinguish Class A combustibles with Class 1 sprays, which may not achieve the fuel wetting necessary to penetrate the char layer. However, Class A fires can be extinguished with Class 1 mists, particularly if the velocity is high, the burning is superficial, or enclosure effects enhance the degree of oxygen reduction. This evidence confirms that drop size distribution alone does not determine the ability of a spray to extinguish a given fire. Factors such as fuel properties, enclosure effects, spray flux density, and spray velocity (momentum) are all involved in determining whether a fire will be extinguished.

The drop size distribution of a spray does not uniquely define its suitability for a given application. It is inseparable from the spray direction relative to the fire plume, its velocity and flux density. The "momentum" of an element of spray is the product of its velocity (which includes direction as well as speed) and the mass of dispersed water droplets. Therefore, all three variables, drop size distribution, flux density and momentum, are involved in determining the ability to extinguish a fire in a given scenario. The classification system allows a designer to distinguish between the fine and coarse end of the spectrum of sprays encompassed by the definition.

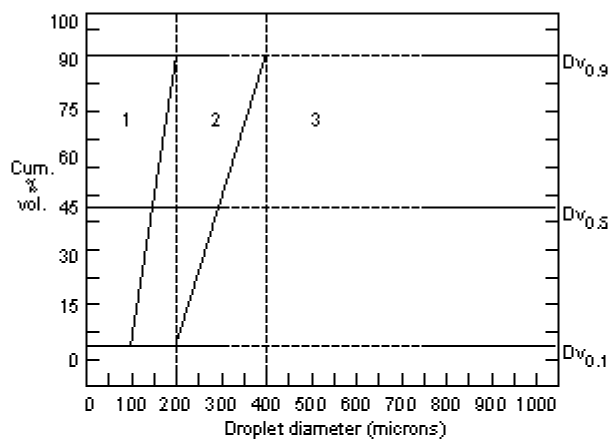


Figure A-1-4.1 Classification of water mist according to drop size distribution.

A-1-5 Applications of Water Mist Systems. Water mist systems have been proven effective in controlling, suppressing, or extinguishing many types of fires. Potential applications include:

(a) Gas jet fires;

(b) Flammable and combustible liquids;

(c) Hazardous solids, including fires involving plastic foam furnishings;

(d) Protection of aircraft occupants from an external pool fire long enough to provide time to escape;

(e) Ordinary (Class A) combustible fires such as paper, wood, and textiles;

(f) Electrical hazards, such as transformers, switches, circuit breakers, and rotating equipment; and

(g) Electronic equipment, including telecommunications equipment.

A-1-5.2.2 Water Reactive Materials. In special cases, where adequate safeguards have been provided, water mist systems for the protection of structures, equipment, or personnel in the presence of such materials as described in 1-5.2.2 may be permitted.

A-1-6.1 Water mist is unlikely to present any significant hazard to personnel in most applications; however, direct impingement of the water mist could present an eye hazard. Noise during operation of the water mist systems could be a hazard to hearing. Water mist can reduce visibility and increase the time and difficulty in egress from an affected compartment. Additionally, whipping or swinging of broken piping, tubing, and hoses could be a hazard, particularly for intermediate and high pressure systems.

A-1-6.2.1 Electrical Clearances. All system components should be located so as to maintain minimum clearances from live parts, as shown in Table A-1-6.2.1.

As used in this standard, "clearance" is the air distance between water mist equipment, including piping and nozzles, and unenclosed or uninsulated live electrical components at other than ground potential.

The clearances in Table A-1-6.2.1 are for altitudes of 3300 ft (1000 m). The clearance should be increased at the rate of 1 percent for each 330 ft (100 m) increase in altitude above 3300 ft (1000 m).

Table A-1-6.2.1 Clearance from Water Mist Equipment Live Uninsulated Electrical Components[1]

	Nominal System Voltage (kV)	Maximum System Voltage (kV)	Design BIL2 (kV)	Minimum[1] Clearance (in.)	Minimum[1] Clearance (mm)
To	13.8	14.5	110	7	178
	23	24.3	150	10	254
	34.5	36.5	200	13	330
	46	48.5	250	17	432

69	72.5	350	25	635
115	121	550	42	1067
138	145	650	50	1270
161	169	750	58	1473
230	242	900 1050	76 84	1930 2134
345	362	1050 1300	84 104	2134 2642
500	550	1500 1800	124 144	3150 3658
765	800	2050	167	4242

[1]For voltages up to 161 kV, the clearances are taken from NFPA 70, *National Electrical Code*. For voltages 230 kV and above, the clearances are taken from Table 124 of ANSI C2, *National Electrical Safety Code*.

[2]BIL values are expressed as kilovolts (kV), the number being the crest value of the full wave impulse test that the electrical equipment is designed to withstand. For BIL values that are not listed in the table, clearances may be found by interpolation.

A-2-2.2.1 Local building codes specify minimum requirements for seismic restraint or bracing.

A-2-2.2.2 Independent inspection and certification is recommended for gas and water containers.

A-2-3.1 It is important to select pipe or tube for water mist systems that exhibits minimal corrosion because of the potential for the clogging of water mist nozzles.

A-2-3.4.2 Listed flexible connections may be permitted. Flexible connections for water mist installations should be kept as short as possible and should be protected against mechanical injury.

A-2-4.1 It is important to select fittings for water mist systems that exhibit minimal corrosion because of the potential for the clogging of water mist nozzles.

A-2-4.2.2 Rubber-gasketed pipe fittings and couplings should not be installed where ambient temperatures can be expected to exceed 150°F (66°C) unless listed for such service. If the manufacturer further limits a given gasket compound, those recommendations should be followed.

A-2-6.1 In recognition of the future value of scientifically based fire protection system engineering or design methods but in consideration of the fact that the present water mist technology base is likely incomplete for general system design purposes, it is recommended that the nozzle-listing agencies collect and report to the manufacturer the following data for possible future use as required listing information:

(a) Cumulative volumetric distribution of water droplets to be measured at the centers on nine 1-ft × 1-ft (0.305-m × 0.305-m) areas projecting outward from the central axis of the nozzle for a total of 3 ft × 3 ft (0.914 m × 0.914 m), in a quadrant, with the plane of the measurements to be oriented perpendicular to the central axis of the nozzle and positioned 39.4 in. (1.0 m) below the nozzle. The measurements are to be made at the minimum- and maximum-rated operating pressures of the nozzle, in accordance with ASTM E 799, *Standard Practice for Determining*

Data Criteria and Processing for Liquid Drop Size Analysis.

(b) Water discharge distribution in a plane 3.3 ft (1.0 m) below and perpendicular to the central axis of the nozzle using 1-ft × 1-ft (0.305-m × 0.305-m) collection pans. The water distribution measurements are to be made at the minimum- and maximum-rated operating pressures of the nozzle and over an area sufficient to collect at least 90 percent of the water discharge.

(c) Profile of the nozzle spray envelope encompassing at least 90 percent of the water discharge, measured from the tip of the nozzle and extending over the effective range determined from the listing investigation. The profile of the nozzle spray envelope is to be provided at the minimum- and maximum-rated operating pressures of the nozzle as well as over the intended range of orientation angles, if in other than the vertically down orientation.

(d) Spray thrust force as measured in a plane perpendicular to the central axis of the nozzle, at a distance of 1 ft (0.305 m) below the nozzle and over an area sufficient to capture at least 90 percent of the water discharge. The measurements are to be made at the minimum- and maximum-rated operating pressures of the nozzle.

For fire test purposes, the maximum distance from test fires should be considered as:

(a) The manufacturer's maximum spacing of nozzles from walls or one half of the manufacturer's recommended maximum spacing between nozzles, whichever is greater; or

(b) The manufacturer's recommended placement of nozzles with regard to local hazard protection.

A-2-10.2.1 Detectors installed at the maximum spacing as listed or approved for fire alarm use could result in excessive delay in water mist system actuation, especially where more than one detection device is required to be in alarm before automatic actuation results.

A-3-2.2.1 The simultaneous operation of all nozzles in the space should be achieved by the use of pilot activation nozzles, automatic nozzles, or by an independent detection system.

A-3-5 Single fluid and twin fluid systems can be operated in the low, intermediate, or high pressure range.

Single Fluid Media Systems. A single fluid media system requires one set of distribution piping to transport the fluid to each nozzle.

Single fluid media systems shall produce water mist (droplet production) by one of the means specified below.

Liquid shall be discharged at a high velocity with respect to the surrounding air. The difference in velocities between the liquid and surrounding air shall shear the liquid into small droplets.

A liquid stream is impinged upon a fixed surface. The impact of the liquid on the surface breaks the liquid stream into small droplets.

Two liquid streams of similar composition collide upon one another. The collision of the two streams breaks the individual streams into small droplets.

Liquid is either vibrated or electrically broken into small droplets (ultrasonic and electrostatic atomizers).

Liquid is heated above its boiling point in a pressurized container and released suddenly to atmospheric pressure (flashing liquid sprays).

Twin Fluid Media Systems. Twin fluid media systems produce water mist (droplet production) by impingement of two fluids delivered from separate piping systems. One set of piping provides a liquid (water) to the nozzle, with the second piping network providing an atomizing fluid/media.

A-4-5.3 When the storage container(s) is placed in the hazard area being protected, provisions shall be made to ensure that the system operation is not adversely affected by its location.

A-4-6.1 Sizing pumps at 120 percent is arbitrary, but it is one way to ensure that the pump curve lies above the system operating point. It could be 110 percent or 150 percent, depending on the degree of conservatism desired. If the system strainer is likely to become partially clogged during operation, the overage should be increased.

A-4-8.1.7 Exception. Sectional control valves and group control valves that are intended to be normally closed, and to be automatically opened by an electrical or pneumatic or hydraulic signal from the system control center, do not have to be locked open. Such control valves should be tested as integral parts of the system and described in the listing literature. The tests for listing of systems incorporating normally closed, remotely activated sectional valves should address concerns about reliability of function.

A-4-9.1.2 In order to prevent system impairment from two or more ground faults or a single open circuit condition, Class A circuits should be considered.

A-4-9.3.1 Detectors installed at the maximum spacing as listed or approved for fire alarm use can result in excessive delay in agent release, especially where more than one detection device is required to be in alarm before automatic actuation results.

A-5-2.1.2.1 Natural ventilation/openings in the compartment allow the hot gases layer (ceiling jet) to exhaust mist from the compartment, decreasing the extinguishing potential. The flow of gases into and out of the compartment also alters the mixing characteristics of the system, which, in turn, might require the additional momentum of the mist in order to overcome this alteration. Forced ventilation also significantly reduces the amount of mist in the compartment as well as affects the mixing characteristics of the system.

Prior to or concurrent with the operation of the water mist system, consideration should be given to automatic closing of doors and dampers, shutdown of electrical equipment, and shutdown of HVAC equipment.

A-5-3.3 Results. The results of the listing testing should identify the following:

(a) System Flow Rate (minimum and maximum).

1. Flow rate per unit area (if applicable); and
2. Flow rate per unit volume (if applicable).

(b) System Operating Pressure (minimum and maximum).

1. Nozzle operating pressure range;
2. Pump/cylinder operating pressure range; and
3. Pump inlet and outlet pressure and flow rate requirements.

(c) General Water Requirements.

1. Quantity/duration;
2. Quality; and
3. Temperature.

(d) Nozzle Characteristics.

1. Type(s)/model numbers;
2. Flow rate (minimum and maximum); and
3. Operating pressure (minimum and maximum).

(e) Nozzle Spray Characteristics.

1. Spray angle;
2. Drop size distribution; and
3. Momentum/velocity.

(f) Nozzle Installation Parameters.

1. Distance above floor (minimum and maximum);
2. Distance below ceiling (minimum and maximum);
3. Distance above hazard (minimum and maximum);
4. Nozzle spacing (minimum and maximum);
5. Orientation;
6. Minimum distance from walls; and
7. Minimum distance from obstructions.

(g) Activation Device.

1. Type/model number;
2. Activation, temperature; and
3. Activation, smoke obscuration.

(h) General Design Parameters.

1. Pipe Requirements.
   a. Size; and
   b. Operating pressures/wall thicknesses.
2. Fittings.
   a. Type; and
   b. Operating pressure.

3. Pumps.

a. Valves, fittings, and filters;

b. Power requirements;

c. Operating pressure and flow rates; and

d. Water requirements.

4. Cylinders.

a. Valves and fittings;

b. Capacity; and

c. Operating pressures.

A-6-1.1 The addition of piping and nozzles to an existing water mist system can render the system ineffective if it leads to reduced pressure and flow. The existing piping does not have to be increased in size to compensate for additional nozzles, provided that the new work is calculated and the calculations include that portion of the existing system that is necessary to carry water or atomizing medium (if used) to the new work.

A-6-2 The Hazen-Williams (H-W) equation cannot be corrected for flow velocity, water temperature, viscosity, or pipe-wall roughness factors, all of which significantly affect the degree of turbulence, hence the pressure losses in piping. Water mist systems in general, and intermediate and high pressure systems in particular [>175 psi to 4000 psi (>12 bar to 270 bar)], are likely to create conditions where there could be higher velocities, different water properties, or smaller diameter pipe than are used in low-pressure systems. (As pipe diameters decrease, the relative effect of wall roughness increases). Because it allows for input of actual fluid properties, the Darcy-Weisbach (D-W) equation should be used instead of the H-W equation for intermediate and high pressure systems.

A-6-3 Many low pressure water mist systems will be similar to standard fire protection systems, such as sprinklers (NFPA 13, *Standard for the Installation of Sprinkler Systems*) and water spray systems (NFPA 15, *Standard for Water Spray Fixed Systems for Fire Protection*). It is expected that piping materials, fittings, valves, and pipe sizes will be selected in accordance with those standards. These expectations imply that velocities in the piping will be in the same range as in sprinkler piping. This assumed similarity to sprinkler piping is the reason this standard accepts the use of the H-W equation for low pressure water mist systems.

Not all low pressure water mist system piping will necessarily be similar to sprinkler piping, however. The designer may choose to use small diameter piping in order to reduce system weight, or, to live with high friction losses in piping in order to be able to install piping in a restricted space, as in an aircraft cargo compartment. Use of small diameter piping will put the velocities higher than is "normal" in sprinkler piping, which introduces the probability that the H-W equation will not be accurate. Values of the friction loss coefficient, C, which is used in the H-W equation, are accurate only if the flow velocity is close to that at which the value of "C" was measured. It is a matter of judgement as to what velocity is "too high" for the H-W equation. American Water Works Association (AWWA) data lists C factors measured at a velocity of 3 ft/sec (0.9 m/s), yet it is accepted practice in sprinkler calculations to have velocities in sprinkler piping between 10 ft/sec and 30 ft/sec (3.05 m/s and 9.1 m/s). Similarly, the tables of equivalent lengths for fittings and valves, used by sprinkler system designers, are based on fittings and valve types typical of sprinkler system. Water mist systems may incorporate different types of fittings and valves, for which the H-W-based equivalent length values will be incorrect. In the interest of "good practice," the water mist system designer should use the D-W equation for low pressure system calculations when pipe sizes or other system features, such as the use of solenoid valves, differ significantly from normal sprinkler practices.

It is also important to note that the H-W equation contains no terms that account for the temperature. Hence, density and viscosity of the liquid also are not taken into account. It assumes that the water contains no additives and is close to 60°F (15.6°C). If viscosity or water temperature depart significantly from typical sprinkler system water supply conditions, the D-W equation should be used instead, regardless of the pressure regime or flow velocities.

A-7-1.2 Although some water discharge might continue after the atomizing medium has been exhausted, it is not effective for fire suppression.

A-7-2 Some water mist systems protect single hazards or areas. Other system designs are based on multiple zones with overlapping protection at the zone boundaries. It is also possible for one water mist system to provide local application protection for several individual hazards. Quantities of water and of atomizing media should be based on the most demanding location for the fire. For example, if a fire could start at the intersection of four zones, the water supply and the atomizing medium (if used) should be able to supply all four zones simultaneously. If a water mist system protects several individual hazards that are located in close proximity, it might be necessary to design for simultaneous operation of multiple local application zones.

A-7-3 The 30-minute water supply requirement applies to water supply capacity and does not require that the system actually discharge for 30 minutes. This minimum duration should be provided for all water mist systems that are installed for life safety purposes or for structural protection. For water mist systems designed to protect equipment or other special hazards in unoccupied areas, Exception No. 1 allows the water supply duration to be determined in accordance with Chapter 5. Exception No. 2 provides for performance-based design of water mist systems by qualified fire protection engineers. It should be noted that, currently, there is no generally accepted method for performance-based design of a water mist system.

A-7-4.1 An extra supply (connected reserve) of extinguishing agent (including additives and atomizing medium, if used) piped to feed into the automatic system should be considered on all installations. The reserve supply is normally actuated by manual operation of the main/reserve switch on either electrically operated or pneumatically operated systems. A connected reserve is desirable for the following reasons:

(a) Provides improved reliability for systems used for protection of life safety;

(b) Provides protection should a reflash occur;

(c) Provides reliability should the main bank malfunction; and

(d) Provides protection of other hazards, if selector valves are involved and multiple hazards are protected by the same set of cylinders.

A-7-5.1 Algae and bacteriological growth in stored water can clog the system by blocking the filters or strainers. Annual sampling or replacement of stored water is required by Table 10-2(b).

A-7-5.5 It is the intention of this section to require a fire department connection wherever it would be of benefit. Exception No. 2 provides for local area protection where the fire department could effectively respond with small hose streams or portable fire extinguishers. Exception No. 3 provides for systems where the pressures available from fire department pumpers would not be adequate to supply the water mist system. Exception No. 4 exempts systems where the atomizing medium is essential for fire suppression, and water alone would be of no benefit.

A-9-2 Acceptance Test Recommendations.

(a) All tests should be made by the contractor in the presence of an authorized inspector. When an inspector is not available, tests may be permitted to be witnessed by the owner or owner's representative.

(b) Before asking for final approval of the protective equipment, installing companies should furnish a written statement to the effect that the work covered by its contract has been completed, and all specified flushing of underground, lead-in, and system piping has been completed, successfully, together with specified hydrostatic pressure tests.

A-9-2.4.2.10 Proper shielding and grounding is particularly important if ac and dc wiring are combined in a common conduit or raceway.

A-10-3.7 The representative sample should include 10 percent of the water mist nozzles in the activated zone. If contamination of filters or strainers is found on inspection, it is recommended that all nozzles within the activated zone also be inspected.

A-11-1.2 Reference is made to standards developed by the International Maritime Organization.

A-11-1.5 Refer to ASTM F 1547, *Standard Guide Listing Relevant Standards and Publications for Commercial Shipbuilding*, 1994, and ASME *Power Piping Code*.

A-11-1.6 Consideration should be given to physically separating the pumping units. It is recommended that not less than 40 percent of the maximum system's flow demand be provided from any single pumping location. Consideration shall be given to using designs incorporating looped systems or arrangements that allow a section to be taken out of service for maintenance. When pumps from another onboard fire protection system, such as fire main pumps, are used to satisfy this requirement, they should be sized to simultaneously supply both systems.

A-11-2.4 An example of an acceptable arrangement is manual operation of a sea chest valve (outside the protected space) to allow continued operation using seawater following the 30-minute stored fresh water operation.

A-11-2.7 Deluge or antifreeze systems may be needed where protected areas are subject to freezing. Piping subject to freezing may be subject to clogging by ice.

A-11-3.3 It is assumed that water mist systems for flammable liquid hazards and compartments require the simultaneous release of water mist from all nozzles in groups of nozzles in the manner of total flooding systems. If systems that operate using individually thermally actuated nozzles are shown by test to have the capability of extinguishing the variety of fires of the machinery space fire test protocol, then manual actuation should cause sufficient nozzles to operate to achieve protection not less effective than that demonstrated in the test protocol.

A-11-3.3.1 An example of an acceptable arrangement is manual operation of a sea chest valve (outside the protected space) to allow continued operation on sea water following the 30-minute stored fresh water discharge.

A-11-3.4 Time delays are optional on water mist systems.

A-11-3.5.6 For systems that cycle, the 15-minute requirement represents 15 minutes at the maximum flow rate, as if the duty cycle was 100 percent for 15 minutes.

Examples include:

Constant. Such as supplied by a pump;

Decaying. Occurs when a pressure cylinder discharges;

Uniform cycling. When a timing device is used to periodically change the pressure or the flow rate; and

Nonuniform cycling. Such as when a heat detector cycles a system on and off.

A-11-3.5.7 Following the depletion of the 30-minute fresh water supply, if continuous sea water operation is provided at a pressure other than that used to successfully perform the machinery space fire tests of 11-3.2.1, the nozzle spray characteristics should be capable of maintaining the cooling of the compartment. Flow rates need not equal those of Safety of Life at Sea (SOLAS) Resolution 10 fixed pressure water spray systems.

A-11-3.6 It is recommended that on passenger ships designed to carry more than 36 persons and on all tank vessels, both the main and emergency sources of power should be from outside the protected space.

A-11-4 The ship's crew will be called upon to inspect, test, maintain, react to, and use some or all parts of the water mist fire suppression system. Therefore, the crew is an integral part of the system. Historically, the crew is the part of the system that system designers and installers have little or no control over. Much of the system will be designed to maintain readiness and operate without human intervention. However, system readiness and operation during an emergency will always involve human interaction with the system. Systems should include design and component features incorporating human factors so as to maximize readiness and utility during a fire.

Appendix B Research Summary

This Appendix is not part of the requirements of this NFPA document but is included for informational purposes only.

Water Mist Droplet Size Characterization and Measurement.

A key mechanism in the successful use of water mist fire protection systems is the increased surface area per unit water volume afforded with the generation and application of small droplets. The increased surface area dramatically increases the rate of heat transfer from the fire to the water mist droplet, cooling the combustion reaction and diluting the oxygen concentration with the generation of water vapor in the vicinity of the fire. It is important to characterize the droplet size distribution produced in listed nozzles for use in the future design and application of water mist systems. It will be valuable in assessing the ability of water mist droplets to control, suppress, and extinguish fires of all types and sizes.

Presently, there are three basic techniques used for the characterization of droplet sizes in a nozzle spray: optical imaging; diffraction; and Doppler refraction. The first technique uses optical technology to photograph or electronically image the droplets in a small volume of the mist. The image is then analyzed to determine the size distribution of droplets on the image.

The second technique uses a collimated light source passed through the water mist. The water droplets diffract the light into a series of detectors. The angle of diffraction is a function of the size of the droplets in the light beam. By measuring the relative light intensities on the detectors, the distribution of droplet sizes can be determined.

The third technique uses a pair of crossed laser beams to generate a small sample volume through which the water droplets pass. The laser light is refracted inside the droplets and detected off-axis. The detector signal is processed to define the droplet size and velocity distributions.

All three techniques are automated in most commercially available measuring instruments, sampling tens of thousands of droplets for the determination of a droplet size distribution. The instruments typically divide the sizes into categories, or "bind," defined by a range of diameters assigned to each bin. Results are then reported as the number of droplets in each bin or as a fractional distribution of number count or total volume in each bin.

Most commercially available measuring instruments also present additional measurements of size distribution significant to the characterization of a water mist. One of these is the Sauter Mean Diameter (SMD), defined as the total volume of the measured droplet population divided by the total surface area of the population. SMD is often used as characteristic dimension when mass transfer (including phase change) is the key process. Another important measurement is the maximum diameter at which a specified fraction of the total volume is accumulated. For example, $Dv_{0.10}$ represents the diameter at which 10 percent of the total volume of the water mist is contained in droplets at or less than the specified diameter. By this definition, $Dv_{0.10}$ represents the volumetric median diameter, that is 50 percent of the total volume of the total water mist is contained in droplets equal to or less than this diameter and 50 percent is contained in droplets of greater diameter.

Appendix C Referenced Publications

C-1 The following documents or portions thereof are referenced within this standard for informational purposes only and thus are not considered part of the requirements of this document. The edition indicated for each reference is the current edition as of the date of the NFPA issuance of this document.

C-1.1 NFPA Publications. National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.

NFPA 13, *Standard for the Installation of Sprinkler Systems,* 1996 edition.

NFPA 15, *Standard for Water Spray Fixed Systems for Fire Protection*, 1996 edition.

NFPA 70, *National Electrical Code*, 1996 edition.

C-1.2 Other Publications.

C-1.2.1 ANSI Publication. American National Standards Institute, 11 West 42nd Street, New York, NY 10036.

ANSI C2-93, *National Electrical Safety Code*, 1993.

C-1.2.2 ASME Publication. American Society of Mechanical Engineers, 345 East 47th Street, New York, NY 10017.

ASME, *Power Piping Code*, 1995.

C-1.2.3 ASTM Publications. American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103.

ASTM E 799, *Standard Practice for Determining Data Criteria and Processing for Liquid Drop Size Analysis*, 1992.

ASTM F 1547, *Standard Guide Listing Relevant Standards and Publications for Commercial Shipbuilding*, 1994.

C-1-2.4 IMO Publication. International Maritime Organization, 4 Albert Embankment, London, SEI 7SR, United Kingdom.

SOLAS Resolution 10, *Fixed Pressure Water Spray Systems*.

NFPA 780

1995 Edition

Standard for the Installation of Lightning Protection Systems

1995 Edition

This edition of NFPA 780, *Standard for the Installation of Lightning Protection Systems*, was prepared by the Technical Committee on Lightning Protection and acted on by the National Fire Protection Association, Inc., at its Annual Meeting held May 22-25, 1995, in Denver, CO. It was issued by the Standards Council with modifications to the document's scope and title, on July 21, 1995, with an effective date of August 11, 1995, and supersedes all previous editions.

This edition of NFPA 780 was approved as an American National Standard on August 18, 1995.

Changes other than editorial are indicated by a vertical rule in the margin of the pages on which they appear. These lines are included as an aid to the user in identifying changes from the previous edition.

Origin and Development of NFPA 780

The National Fire Protection Association first adopted *Specifications for Protection of Buildings Against Lightning* in 1904. Revised standards were adopted in 1905, 1906, 1925, 1932, and 1937. In 1945, the NFPA Committee and the parallel ASA Committee on Protection Against Lightning were reorganized and combined under the sponsorship of the NFPA, the National Bureau of Standards, and the American Institute of Electrical Engineers (now the IEEE). In 1946, the NFPA acted to adopt Part III and in 1947 published a revised edition incorporating this part. Further revisions, recommended by the Committee, were adopted by the NFPA in 1949, 1950, 1951, 1952, 1957, 1959, 1963, 1965, 1968, 1975, 1977, 1980, 1983, 1986, 1989, and 1992.

Commencing with the 1992 edition of the *Lightning Protection Code*, the NFPA numerical designation of the document was changed from NFPA 78 to NFPA 780.

Commencing with the current edition, the name of the document has been changed from *Lightning Protection Code* to *Standard for the Installation of Lightning Protection Systems*. This change was directed by the Standards Council on issuance of the document in order to make the title more accurately reflect the document's content. In addition, the Council directed certain changes to the scope of the document in order to clarify that the document does not cover lightning protection installation requirements for early streamer emission systems or lightning dissipator array systems.

In issuing this document, the Standards Council has noted that lightning is a stochastic, if not capricious, natural process. Its behavior is not yet completely understood. This standard is intended to provide requirements, within the limits of the current state of knowledge, for the installation of those lightning protection systems covered by the standard.

Notice

Following the issuance of this edition of NFPA 780, *Standard for the Installation of Lightining Protection Systems*, by the NFPA Standards Council, an appeal was filed with the NFPA Board of Directors. At the time of printing, this appeal was pending.

The appeal requests that the Board of Directors reverse the Standards Council decision to issue the 1995 edition of NFPA 780.

NFPA will announce the disposition of the appeal when it has been determined. Anyone wishing to receive the disposition of the appeal should notify in writing the Secretary, Standards Council, NFPA, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.

Technical Committee on Lightning Protection

Mitchell Guthrie, *Chair*
Universal Systems Inc., VA

Burt J. Bittner, Harris Corp., FL

Roy B. Carpenter, Jr., Lightning Eliminators & Consultants Inc., CO

Ignacio T. Cruz, U.S. Dept. of Defense, VA

Dennis P. Dillon, Bonded Lightning Protection, Inc., FL
Rep. Lightning Protection Inst.

Thomas P. Dowling, Inst. of Makers of Explosives, DC

Douglas J. Franklin, Thompson Lightning Protection Inc., MN

Paul S. Hamer, Chevron Research & Technology Co., CA
Rep. American Petroleum Inst.

Thomas R. Harger, Harger Lightning Protection Inc., IL

William E. Heary, Lightning Preventors of America Inc., NY

Bruce A. Kaiser, Lightning Master Corp., FL

Richard W. Kragh, Kragh Engineering Inc., IL

Henry M. Lancaster, Warren Lightning Rod Co., NJ
Rep. United Lightning Protection Assn., Inc

Edward A. Lobnitz, Tilden Lobnitz & Cooper Inc., FL

William J. Maurits, U.S. DOD Explosives Safety Board, VA

David E. McAfee, Westinghouse Savannah River Co., SC

R. B. Melton, Jr., Bell South Telecom, Inc., GA
Rep. Alliance for Telecommunications Industry Solutions

Charles R. Prasso, Industrial Risk Insurers, CT
Rep. Industrial Risk Insurers

Timothy E. Russell, Underwriters Laboratories Inc., IL

Harold G. VanSickle, A-C Lightning Security Inc., MO

Lynn C. Wall, Sedgwick James of Georgia, GA

Alternates

Charles H. Ackerman, East Coast Lightning Equipment Inc., CT
(Alt. to D. P. Dillon)

Norman L. Fowler, U.S. Air Force, FL
(Alt. to I. T. Cruz)

Kenneth P. Heary, Lightning Preventor of America Inc., NY
(Alt. to W. E. Heary)

David A. Otto, Underwriters Laboratories Inc., IL
(Alt. to T. E. Russell)

Terrance K. Portfleet, Michigan Lightning Protection Co., MI
(Alt. to H. M. Lancaster)

Allan P. Steffes, Thompson Lightning Protection Inc., MN
(Alt. to D. J. Franklin)

Harold (Bud) VanSickle, III, A-C Lightning Security Inc., MO
(Alt. to H. G. VanSickle)

John M. Caloggero, NFPA Staff Liaison

This list represents the membership at the time the Committee was balloted on the text of this edition. Since that time, changes in the membership may have occurred.

NOTE: Membership on a Committee shall not in and of itself constitute an endorsement of the Association or any document developed by the Committee on which the member serves.

Committee Scope: This Committee shall have primary responsibility for documents on the protection from lightning of buildings and structures, recreation and sports areas, and any other situations involving danger from lightning to people or property, except those concepts utilizing early streamer emission air terminals. The protection of electric generating, transmission, and distribution systems is not within the scope of this Committee.

NFPA 780
Standard for the Installation of Lightning Protection Systems

1995 Edition

NOTICE: An asterisk (*) following the number or letter designating a paragraph indicates explanatory material on that paragraph in Appendix A.
Information on referenced publications can be found in Appendix M.

Chapter 1 Introduction

1-1 Scope.

1-1.1

This document covers lightning protection system installation requirements for:

(a) ordinary structures;

(b) miscellaneous structures and special occupancies;

(c) heavy duty stacks;

(d) watercraft; or

(e) structures containing flammable vapors, flammable gases, or liquids that can give off flammable vapors.

1-1.2*

This document does not cover lightning protection installation requirements for:

(a) explosives manufacturing buildings and magazines; or

(b) electric generating, transmission, and distribution systems.

1-1.3

This document does not cover lightning protection installation requirements for early streamer emission systems or lightning dissipator array systems.

1-2 Purpose.

The purpose of this standard is the practical safeguarding of persons and property from hazards arising from exposure to lightning.

1-3 Listed, Labeled, or Approved Components.

Where fittings, devices, or other components required by this standard are available as Listed or Labeled, such components shall be used. Otherwise, such components shall be approved by the authority having jurisdiction.

1-4 Mechanical Execution of Work.

Lightning protection systems shall be installed in a neat and workmanlike manner.

Chapter 2 Terms and Definitions

2-1 General Terminology.

General terms commonly used in describing lightning protection methods and devices are defined or redefined to conform to recent trends:

Lightning Protection System. This term refers to systems as described and detailed in this standard. A lightning protection system is a complete system of air terminals, conductors, ground terminals, interconnecting conductors, surge suppression devices, and other connectors or fittings required to complete the system.

2-2* Definitions.

Air Terminal. An air terminal is that component of a lightning protection system that is intended to intercept lightning flashes. [*See Figure A-2-2(a).*]

Approved.* Acceptable to the authority having jurisdiction.

Authority Having Jurisdiction.* The organization, office, or individual responsible for approving equipment, an installation, or a procedure.

Bonding. An electrical connection between an electrically conductive object and a component of a lightning protection system that is intended to significantly reduce potential differences created by lightning currents. [*See Figure A-2-2(b).*]

Cable. A conductor formed of a number of wires stranded together. [*See Figure A-2-2(c) and Tables 3-4 and 3-5.*]

Chimney. A smoke or vent stack having a flue with a cross-sectional area less than 500 $in.^2$ (0.3 m^2) and a total height less than 75 ft (23 m). [*See Figure A-2-2(d).*]

Class I Materials. Lightning conductors, air terminals, ground terminals, and associated fittings required by this standard for the protection of structures not exceeding 75 ft (23 m) in height. [*See Figure A-2-2(e) and Table 3-4.*]

Class II Materials. Lightning conductors, air terminals, ground terminals, and associated fittings required by this standard for the protection of structures exceeding 75 ft (23 m) in height. [*See Figure A-2-2(e) and Table 3-5.*]

Combustible Liquid. A liquid having a flash point at or above 100°F (37.8°C).

Combustible liquids shall be subdivided as follows:

Class II liquids shall include those having flash points at or above 100°F (37.8°C) and below 140°F (60°C).

Class IIIA liquids shall include those having flash points at or above 140°F (60°C) and below 200°F (93°C).

Class IIIB liquids shall include those having flash points at or above 200°F (93°C).

Conductor, Bonding. A conductor intended to be used for potential equalization between grounded metal bodies and the lightning protection system.

Conductor, Main. A conductor intended to be used to carry lightning currents between air terminations and ground terminals.

Copper-clad Steel. Steel with a coating of copper bonded to it.

Explosive Materials. These include explosives, blasting agents, and detonators as authorized for transportation by the Department of Transportation or the Department of Defense.

Fastener. An attachment to secure the conductor to the structure.

Flame Protection. Self-closing gauge hatches, vapor seals, pressure-vacuum breather valves, flame arresters, or other reasonably effective means to minimize the possibility of flame entering the vapor space of a tank.

Flammable Air-Vapor Mixtures. When flammable vapors are mixed with air in certain proportions, the mixture will burn rapidly when ignited. The combustion range for ordinary petroleum products, such as gasoline, is from about $1^1/_2$ to $7^1/_2$ percent of vapor by volume, the remainder being air.

Flammable Liquid. A liquid having a flash point below 100°F (37.8°C) and having a vapor pressure not exceeding 40 psia (275 kPa) at 100°F (37.8°C) shall be known as a Class I liquid.

Class I liquids shall be subdivided as follows:

Class IA shall include those having flash points below 73°F (22.8°C) and having a boiling point below 100°F (37.8°C).

Class IB shall include those having flash points below 73°F (22.8°C) and having a boiling point at or above 100°F (37.8°C).

Class IC shall include those having flash points at or above 73°F (22.8°C) and below 100°F (37.8°C).

Flammable Vapors. The vapors given off from a flammable or combustible liquid at or above its flash point.

Flash Point. The minimum temperature at which a liquid gives off vapor in sufficient concentration to form an ignitable mixture with air near the surface of the liquid within the vessel, as specified by appropriate test procedure and apparatus.

Gastight. Structures so constructed that gas or air can neither enter nor leave the structure except through vents or piping provided for the purpose.

Ground Terminal. The portion of a lightning protection system such as a ground rod, ground plate, or ground conductor that is installed for the purpose of providing electrical contact with the earth. [*See Figure A-2-2(f).*]

Grounded. Connected to earth or to some conducting body that is connected to earth.

High-Rise Building. For the purposes of this standard a high-rise building is a structure exceeding 75 ft (23 m) in height.

Labeled. Equipment or materials to which has been attached a label, symbol, or other identifying mark of an organization that is acceptable to the authority having jurisdiction and concerned with product evaluation that maintains periodic inspection of production of labeled equipment or materials and by whose labeling the manufacturer indicates compliance with appropriate standards or performance in a specified manner.

Listed.* Equipment or materials included in a list published by an organization acceptable to the authority having jurisdiction and concerned with product evaluation that maintains periodic inspection of production of listed equipment or materials and whose listing states either that the equipment or material meets appropriate standards or has been tested and found suitable for use in a specified manner.

Loop Conductor. A conductor encircling a structure that is used to interconnect ground terminals, main conductors, or other grounded bodies.

Metal-clad Structure. A structure with sides or roof, or both, covered with metal.

Metal-framed Structure. A structure with electrically continuous structural members of sufficient size to provide an electrical path equivalent to that of the lightning conductors covered in this standard.

Shall. Indicates a mandatory requirement.

Should. Indicates a recommendation or that which is advised but not required.

Sideflash. An electrical spark, caused by differences of potential, occurring between conductive metal bodies or between such metal bodies and a component of the lightning protection system or ground. [*See Figure A-2-2(g).*]

Spark Gap. As used in this standard, the term spark gap means any short air space between two conductors electrically insulated from or remotely electrically connected to each other.

Stack, Heavy-duty. A smoke or vent stack is classified as heavy-duty if the cross-sectional area of the flue is greater than 500 in.^{2} (0.3 m^2) or the height is greater than 75 ft (23 m).

Striking Distance. The distance over which the final breakdown of the initial stroke occurs.

Surge Arrester. A protective device for limiting surge voltages by discharging or bypassing surge current. It also prevents continued flow of follow current while remaining capable of repeating these functions.

Vapor Openings. Openings through a tank shell or roof above the surface of the stored liquid. Such openings might be provided for tank breathing, tank gauging, fire fighting, or other operating purposes.

Watercraft. For the purpose of this document, watercraft is defined as all forms of boats and vessels up to 300 gross tons (272 metric tons) used for pleasure or commercial purposes, but excluding seaplanes, hovercraft, vessels with a cargo of flammable liquids, and submersible vessels.

Zone of Protection. The zone of protection is that space adjacent to a lightning protection system that is substantially immune to direct lightning flashes.

2-3 Metric Units of Measurement.

Metric units of measurement in this standard are in accordance with the modernized metric system known as the International System of Units (SI). If a value for measurement as given in this standard is followed by an equivalent value in other units, the first stated is to be regarded as the requirement. A given equivalent value might be approximate.

Chapter 3 Protection for Ordinary Structures

3-1 General.

An ordinary structure is one that is used for ordinary purposes whether commercial, industrial, farm, institutional, or residential. Ordinary structures not exceeding 75 ft (23 m) in height shall be protected with Class I materials as shown in Table 3-4. Ordinary structures greater than 75 ft (23 m) in height shall be protected with Class II materials as shown in Table 3-5.

3-1.1 Roof Types and Pitch.

For the purpose of this standard, roof types and pitches are as shown in Figures 3-1.1(a) and 3-1.1(b).

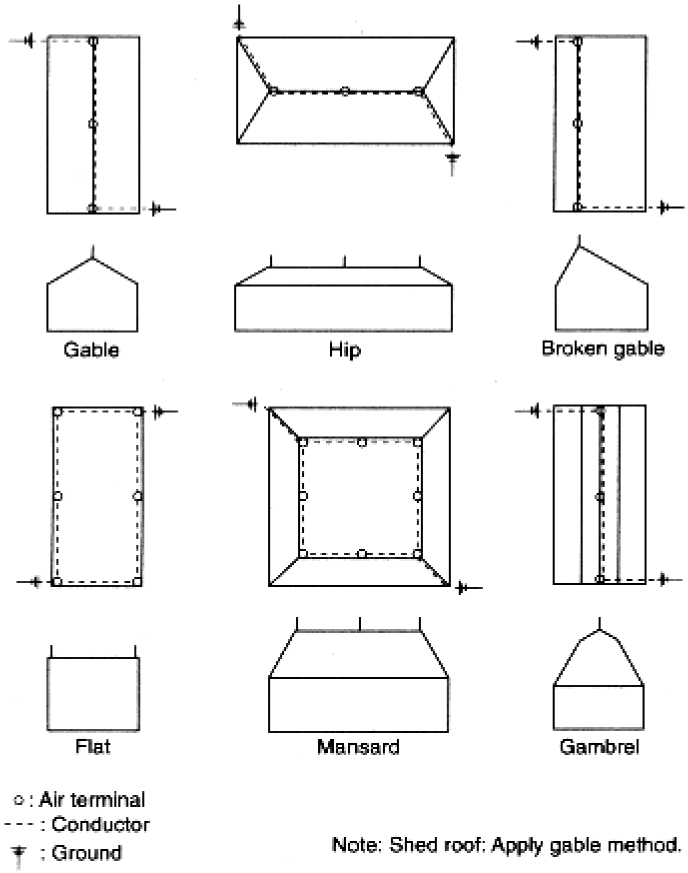


Figure 3-1.1(a) Roof types: protection methods (drawings are top and end views of each roof type).

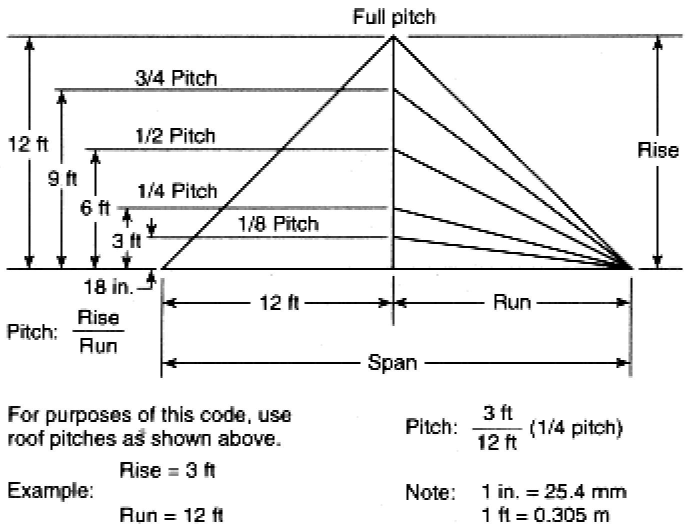


Figure 3-1.1(b) Roof pitch.

3-2 Materials.

The materials protection systems are made of shall be resistant to corrosion or shall be acceptably protected against corrosion. No combination of materials shall be used that forms an electrolytic couple of such nature that in the presence of moisture corrosion is accelerated. One or more of the following materials shall be used:

(a) *Copper*. Where copper is used it shall be of the grade ordinarily required for commercial electrical work, generally designated as being of 95-percent conductivity when annealed.

(b) *Copper Alloys*. Where alloys of copper are used they shall be substantially as resistant to corrosion as copper under similar conditions.

(c) *Aluminum*. Where aluminum is used, care shall be taken not to use it in contact with the earth or elsewhere where it will rapidly deteriorate. Conductors shall be of electrical grade aluminum.

(d) Copper lightning protection materials shall not be installed on aluminum roofing, siding, or other aluminum surfaces.

(e) Aluminum lightning protection materials shall not be installed on copper surfaces.

3-3 Form and Size.

Air terminals shall be made of solid or tubular rods. Conductors shall be in the form of multiple strand cables, single wires or rods, or flat strips, sized as shown in Tables 3-4 and 3-5. Ground terminals shall be made of rods, plates, or stranded cables.

3-4 Materials, Class I.

Table 3-4 gives minimum sizes and weights for air terminals and conductors for use on ordinary buildings and structures not exceeding 75 ft (23 m) in height.

Table 3-4 Class I Material Requirements

Type of Conductor		Copper		Aluminum	
		Standard	Metric	Standard	Metric
Air Terminal, Solid	Min. Diameter	⅜ in.	9.5 mm	½ in.	12.7 mm
Air Terminal, Tubular	Min. Diameter Min. Wall Thickness	⅝ in. 0.033 in.	15.9 mm 0.8 mm	⅝ in. 0.064 in.	15.9 mm 1.6 mm
Main Conductor, Cable	Min. Size ea. Strand Wgt. per Length Cross Sect. Area	17 AWG 187 lb/1000 ft 57,400 CM	 278 g/m 29 mm^2	14 AWG 95 lb/1000 ft 98,600 CM	 141 g/m 50 mm^2
Main Conductor, Solid Strip	Thickness Width	0.051 in. 1 in.	1.30 mm 25.4 mm	0.064 in. 1 in.	1.63 mm 25.4 mm
Bonding Conductor, Cable (solid or stranded)	Min. Size ea. Strand Cross Sect. Area	17 AWG 26,240 CM		14 AWG 41,100 CM	
Bonding Conductor, Solid Strip	Thickness Width	0.051 in. ½ in.	1.30 mm 12.7 mm	0.064 in. ½ in.	1.63 mm 12.7 mm

3-5 Materials, Class II.

Table 3-5 gives minimum sizes and weights for air terminals and conductors for use on ordinary buildings and structures exceeding 75 ft (23 m) in height. If part of a structure is over 75 ft (23 m) in height (as a steeple), and the remaining portion is less than 75 ft (23 m) in height, the requirements for Class II air terminals and conductors shall apply only to that portion over 75 ft (23 m) in height. Class II conductors from the higher portion shall be extended to ground and shall be interconnected with the balance of the system.

Table 3-5 Class II Material Requirements

Type of Conductor		Copper		Aluminum	
		Standard	Metric	Standard	Metric
Air Terminal, Solid	Min. Diameter	½ in.	12.7 mm	⅝ in.	15.9 mm
Main Conductor, Cable	Min. Size ea. Strand Wgt. per Length Cross Sect. Area	15 AWG 375 lb/1000 ft 115,000 CM	 558 g/m 58 mm^2	13 AWG 190 lb/1000 ft 192,000 CM	 283 g/m 97 mm^2
Bonding Conductor, Cable (solid or stranded)	Min. Size ea. Strand Cross Sect. Area	17 AWG 26,240 CM		14 AWG 41,100 CM	
Bonding Conductor, Solid Strip	Thickness Width	0.051 in. ½ in.	1.30 mm 12.7 mm	0.064 in. ½ in.	1.63 mm 12.7 mm

3-6 Corrosion Protection.

Precautions shall be taken to provide the necessary protection against any tendency towards deterioration of any lightning protection component due to local conditions. Copper components installed within 24 in. (600 mm) of the top of a chimney or vent emitting corrosive gases shall be protected by a hot-dipped lead coating or equivalent.

3-7 Mechanical Damage or Displacement.

Any part of a lightning protection system that is subject to mechanical damage or displacement shall be protected with a protective molding or covering. If metal pipe or tubing is used around the conductor, the conductor shall be electrically connected to the pipe or tubing at both ends.

3-8 Use of Aluminum.

Aluminum systems shall be installed in accordance with other applicable sections and with the following:

(a) Aluminum lightning protection equipment shall not be installed on copper-roofing materials or other copper surfaces, or where exposed to the runoff from copper surfaces.

(b) Aluminum materials shall not be used where they come into direct contact with earth. Fittings used for the connection of aluminum-down conductors to copper or copper-clad grounding equipment shall be of the bimetallic type. Bimetallic connectors shall be installed not less than 18 in. (457 mm) above earth level.

(c) Connectors and fittings shall be suitable for use with the conductor and the surfaces on which they are installed. Bimetallic connectors and fittings shall be used for splicing or bonding dissimilar metals.

(d) An aluminum conductor shall not be attached to a surface coated with alkaline-base paint, embedded in concrete or masonry, or installed in a location subject to excessive moisture.

3-9 Air Terminals.

Air terminals shall be provided for all parts of a structure that are likely to be damaged by direct lightning flashes. Metal parts of a structure that are exposed to direct lightning flashes and that have a metal thickness of $^{3}/_{16}$ in. (4.8 mm) or greater only require connection to the lightning protection system. Such connections shall provide a two-way path to ground as is required for air terminals. Air terminals shall not be required for those parts of a structure located within a zone of protection.

3-9.1 Height.

The tip of an air terminal shall be not less than 10 in. (254 mm) above the object or area it is to protect, except as permitted by Section 3-11. (*See Figure 3-9.1.*)

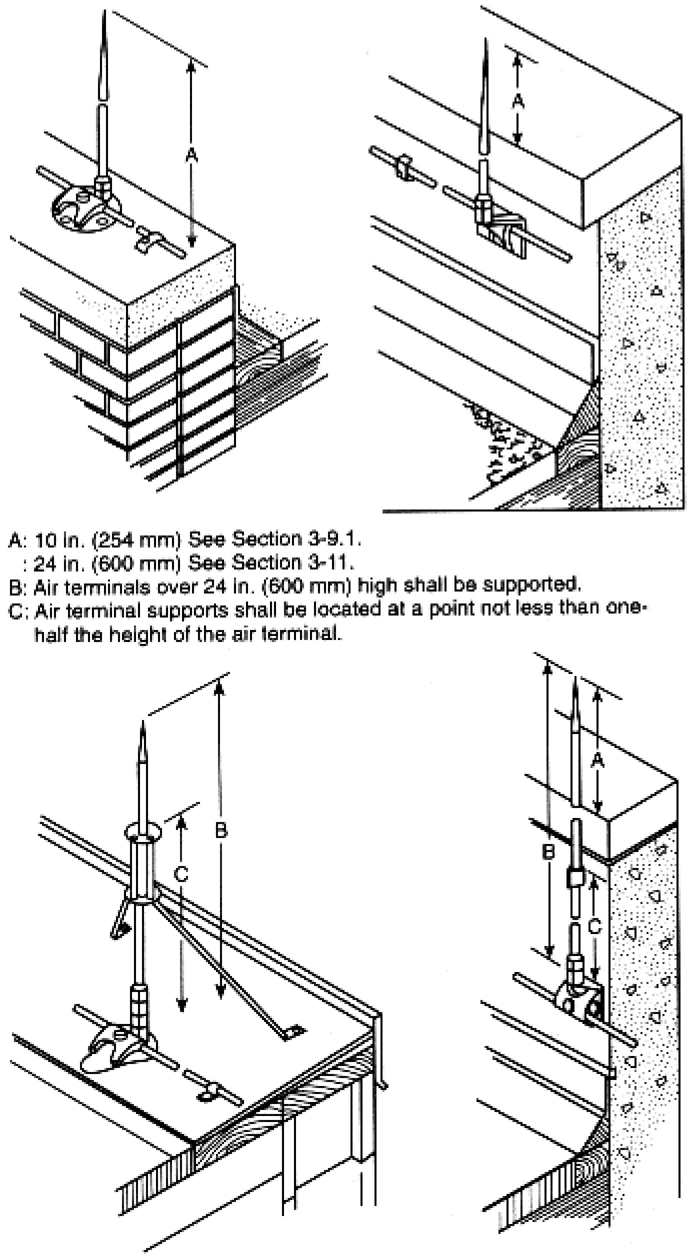


Figure 3-9.1 Air terminal height.

3-9.2 Support.

Air terminals shall be secured against overturning either by attachment to the object to be protected or by means of braces that shall be permanently and rigidly attached to the building. An air terminal exceeding 24 in. (600 mm) in height shall be supported at a point not less than one-half its height.

3-9.3 Ornaments.

An ornament or decoration on a freestanding, unbraced air terminal shall not present, in any plane, a wind-resistance area in excess of 20 in.^{2} (0.01 m^2). This permits the use of an ornamental ball 5 in. (127 mm) in diameter.

3-10 Zones of Protection.

To determine the zone of protection, the geometry of the structure shall be considered. The zone of protection is described in 3-10.1 through 3-10.3.

3-10.1

For flat or gently sloping roofs, dormers, domed roofs, and roofs with ridges, wells, chimneys, or vents, the zone of protection includes the roof and appurtenances where protected in accordance with Section 3-11.

3-10.2

For structures with multiple level roofs no more than 50 ft (15 m) in height, the zone of protection includes areas as identified in 3-10.2.1 and 3-10.2.2. The zone of protection forms a cone having an apex at the highest point of the air terminal, with walls forming approximately a 45- or 63-degree angle from the vertical.

3-10.2.1 Structures that do not exceed 25 ft (7.6 m) above earth are considered to protect lower portions of a structure located in a one-to-two zone of protection as shown in Figures 3-10.2.1(a) and 3-10.2.1(b).

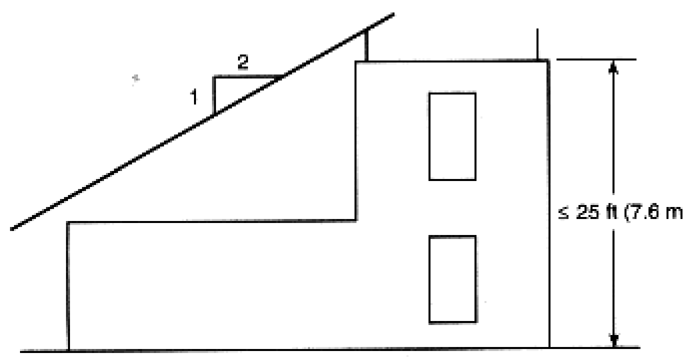


Figure 3-10.2.1(a) Lower roof protection for flat roof buildings 25 ft (7.6 m) or less in height.

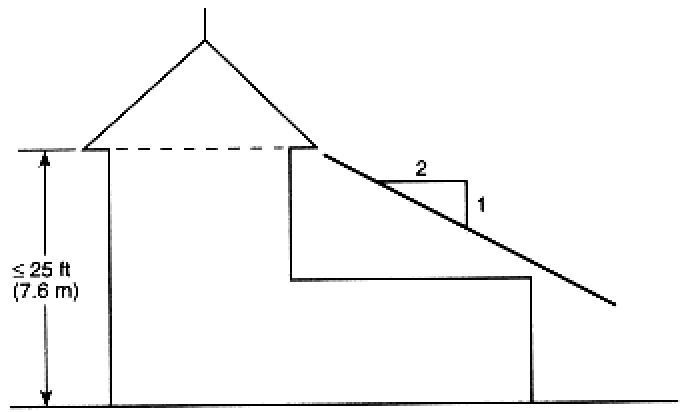


Figure 3-10.2.1(b) Lower roof protection provided by pitched roof buildings 25 ft (7.6 m) or less in height.

3-10.2.2 Structures that do not exceed 50 ft (15 m) above earth are considered to protect lower portions of a structure located within a one-to-one zone of protection as shown in Figures 3-10.2.2(a) and 3-10.2.2(b).

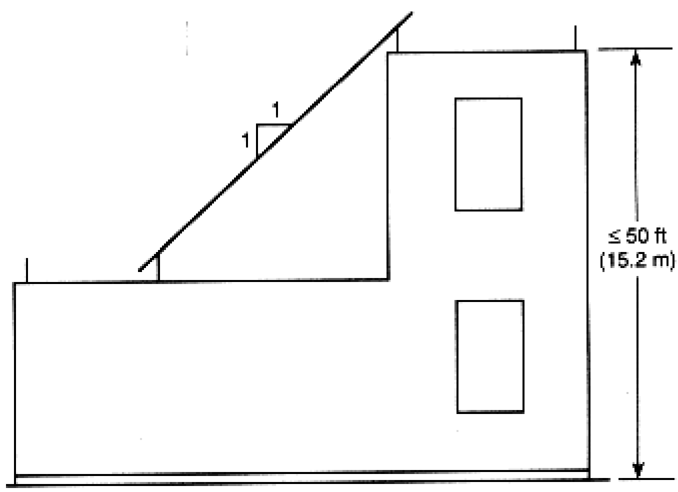


Figure 3-10.2.2(a) Lower roof protection for buildings 50 ft (15.24 m) or less in height.

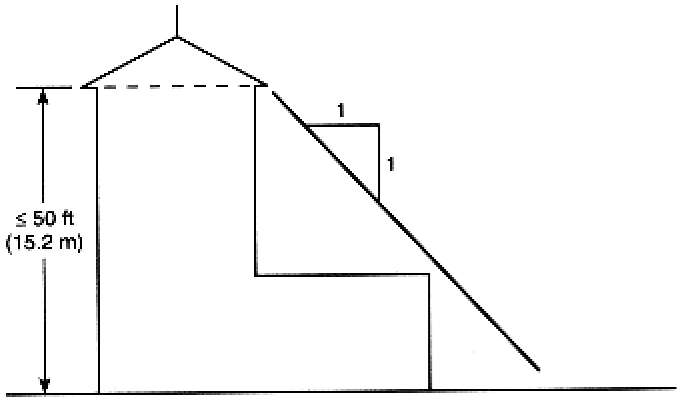


Figure 3-10.2.2(b) Lower roof protection provided by pitched roof buildings 50 ft (15.24 m) or less in height.

3-10.3 Rolling Sphere Concept.

3-10.3.1 The zone of protection includes the space not intruded by a rolling sphere having a radius of 150 ft (46 m). When tangent to earth and resting against a lightning protection air terminal, all space between the two points of contact and under the sphere are in the zone of protection. A zone of protection is also formed when such a sphere is resting on two or more air terminals and includes the space under the sphere between those terminals, as shown in Figure 3-10.3.1. All possible placements of the sphere must be considered when determining the zone of protection using the rolling sphere concept.

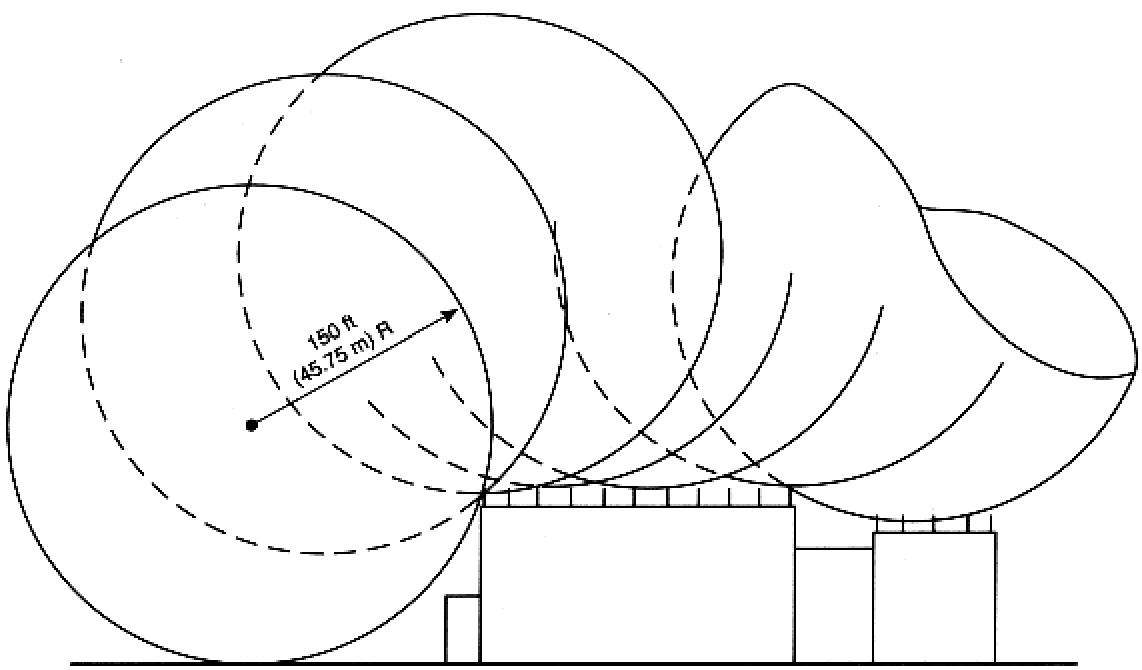
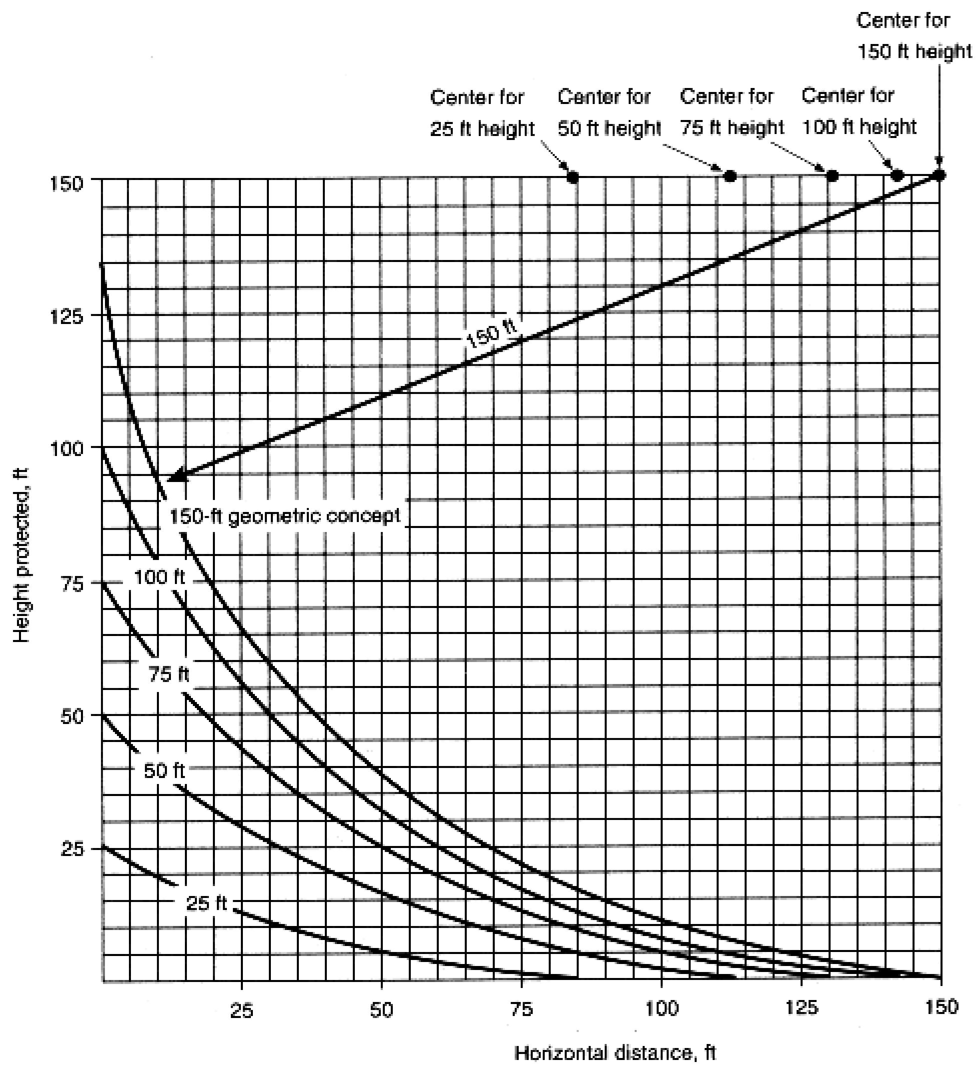


Figure 3-10.3.1.

3-10.3.2 For structure heights exceeding 150 ft (46 m) above earth or above a lower air terminal, the zone of protection is considered to be the space between the points of contact and under the sphere, when it is resting against a vertical surface of the structure and the lower air terminal or earth. The zone of protection is limited to the space above the horizontal plane of the lowest terminal unless it can be extended by further analysis, such as in rolling the sphere to be tangent to earth.

3-10.3.3 Figure 3-10.3.3 provides a graphic representation of the 150-ft (46-m) geometric concept for structures of selected heights up to 150 ft (46 m). Based on the height of the air terminal on a protected structure being 25 ft (7.6 m), 50 ft (15 m), 75 ft (23 m), 100 ft (30 m), or 150 ft (46 m) above ground, reference to the appropriate curve shows the anticipated zone of protection for objects and roofs at lower elevations. The graph shows the protected distance ("horizontal distance") as measured radially from the protected structure. The horizontal distance thus determined applies only at the horizontal plane of the "height protected."



Note: 1 ft = 0.305 m

Figure 3-10.3.3 Zone of protection.

3-10.3.4 Under the rolling sphere concept, the horizontal protected distance found geometrically by Figure 3-10.3.3 ("horizontal distance, ft") can also be calculated using the formula:

$$d = \sqrt{h_1 (300 - h_1)} - \sqrt{h_2 (300 - h_2)}$$

Where:

d = horizontal distance, ft

h_1 = height of the higher roof, ft

h_2 = height of the lower roof (top of the object), ft

Use of this formula is based on a 150 ft (46 m) striking distance.

For the formula to be valid, the sphere must be tangent to either the lower roof or in contact with the earth, and in contact with the vertical side of the higher portion of the structure. In addition, the difference in heights between the upper and lower roofs or earth must be 150 ft (46 m) or less.

3-11 Air Terminals on Roofs.

Air terminals shall be placed on ridges of pitched roofs and around the perimeter of flat or gently sloping roofs at intervals not exceeding 20 ft (6 m). Air terminals of 24 in. (600 mm) above the object or area to be protected are permitted to be placed at intervals not exceeding 25 ft (7.6 m). Air terminals shall be placed at or within 2 ft (0.6 m) of the ends of ridges on pitched roof buildings, or at edges and outside corners of flat or gently sloping roofs. [*See Figures 3-11, 3-11.1(a) and (b)*]. In the case of tall structures having a pitched roof with eaves height of 50 ft (15 m) or less above grade, only the ridge requires protection provided the roof pitch is $^1/_4$ or greater and there is no horizontal portion of the building that extends beyond the eaves, other than a gutter. For pitched roof buildings with an eaves height over 50 ft (15 m), the 150-ft (46-m) geometric concept shall be used to calculate air terminal locations. [*See Figures 3-10.3.1, 3-11, 3-11.1(a) and (b)*].

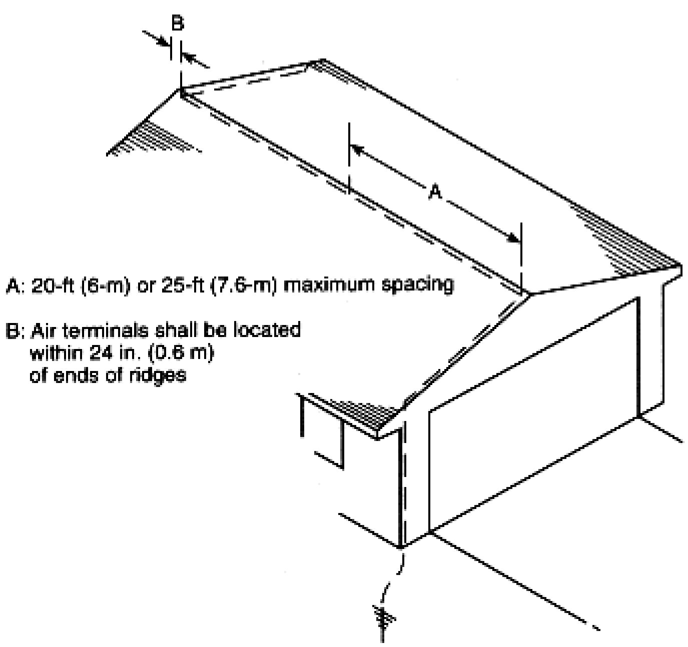


Figure 3-11 Air terminals on peaked roof.

3-11.1 Flat or Gently Sloping Roofs.

Flat or gently sloping roofs that exceed 50 ft (15 m) in width or length shall have additional air terminals located at intervals not to exceed 50 ft (15 m) on the flat or gently sloping areas.

Gently sloping roofs are defined as: (1) those roofs having a span of 40 ft (12 m) or less and a pitch of less than $^1/_8$; and (2) those roofs having a span of more than 40 ft (12 m) and a pitch of less than $^1/_4$. [*See Figures 3-11.1(a) and 3-11.1(b).*]

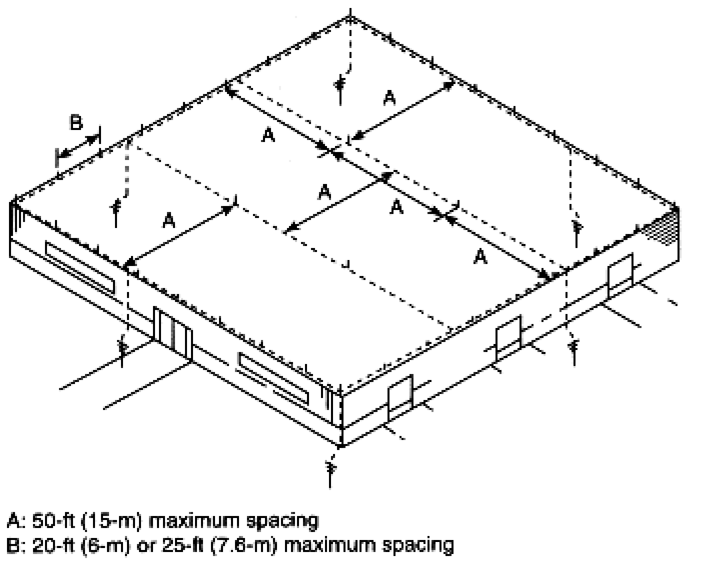


Figure 3-11.1(a) Air terminals on flat roof.

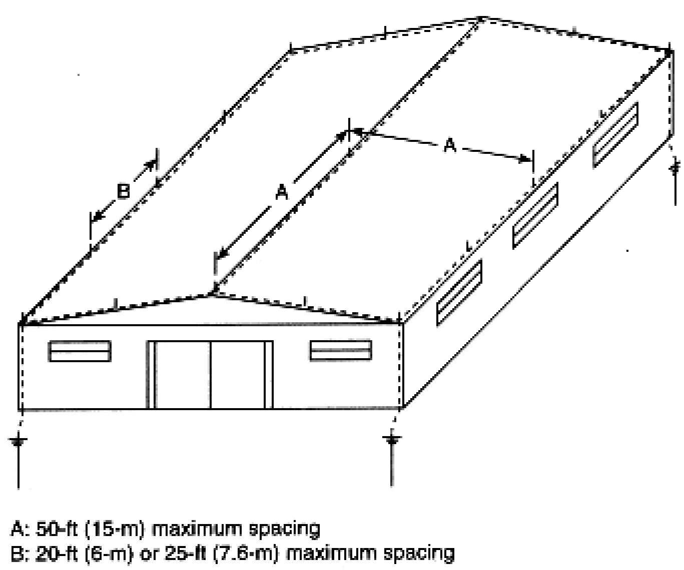


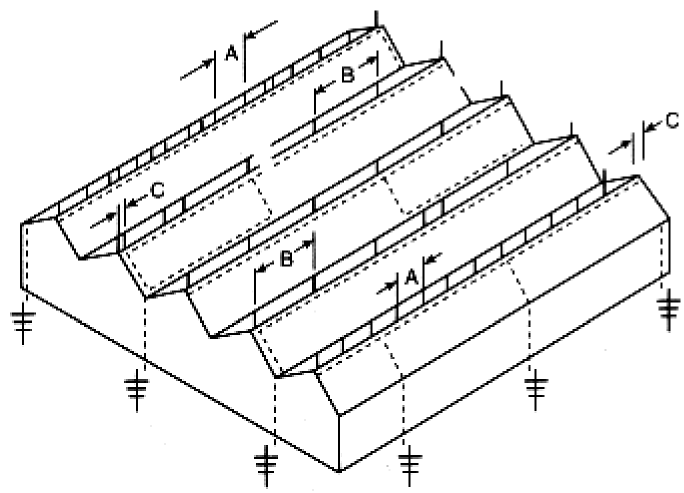
Figure 3-11.1(b) Air terminals on gently sloping roof.

3-11.2* Dormers.

Dormers as high or higher than the main roof shall be protected with air terminals, cable, down conductors, and grounds as normally specified. Dormers and projections below the main ridge require protection only on those areas extending outside a zone of protection.

3-11.3 Roofs with Intermediate Ridges.

Air terminals shall be located along the outermost ridges of buildings that have a series of intermediate ridges at the same intervals as required by Section 3-11. Air terminals shall be located on the intermediate ridges in accordance with the requirements for the spacing of air terminals on flat or gently sloping roofs. If any intermediate ridge is higher than the outermost ridges, it shall be treated as a main ridge and protected according to Section 3-11. (*See Figure 3-11.3.*)



Maximum spacings:

A: 20 ft (6 m) or 25 ft (7.6 m)
B: 50 ft (15 m)
C: 2 ft (610 mm)

Figure 3-11.3 Air terminals on intermediate ridges.

3-11.4 Flat or Gently Sloping Roofs with Irregular Perimeters.

Structures that have exterior wall designs that result in irregular roof perimeters shall be treated on an individual basis. In many cases the outermost projections form an “imaginary” roof edge that is used to locate the terminals in accordance with Section 3-11. In all cases, however, air terminals shall be located in accordance with Section 3-11 through 3-11.7. [*See Figure 3-11.4(a).*]

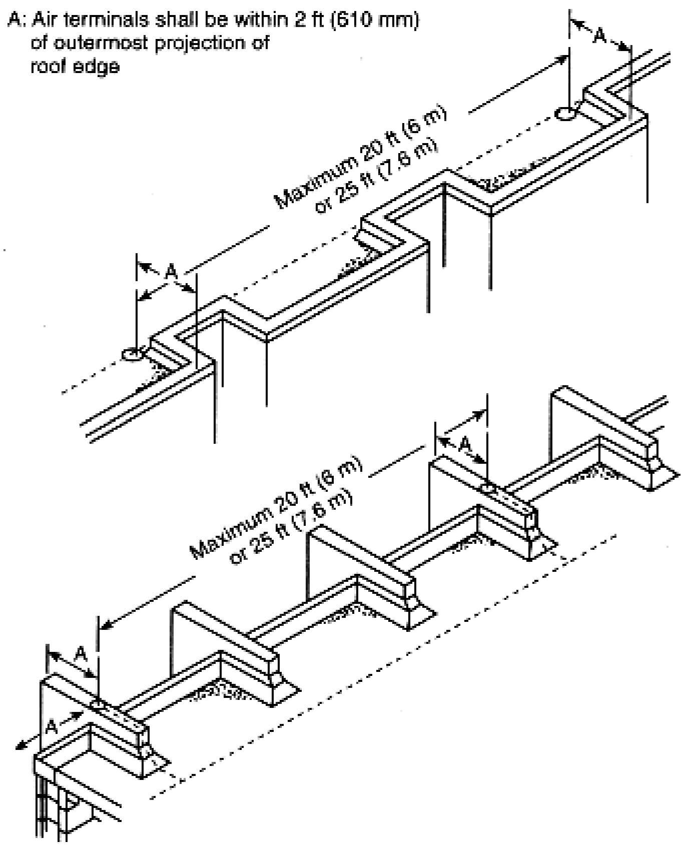


Figure 3-11.4(a) Flat or gently sloping roof with irregular perimeter.

Air terminals installed on vertical roof members shall be permitted to use a single sized cable to a main roof conductor. The main roof conductor shall be run adjacent to the vertical roof members so that the single cable from the air terminal is as short as possible and, in any case, no longer than 16 ft (4.9 m). The connection of the single cable to the down conductor shall be made with a tee splice. [*See Figure 3-11.4(b).*]

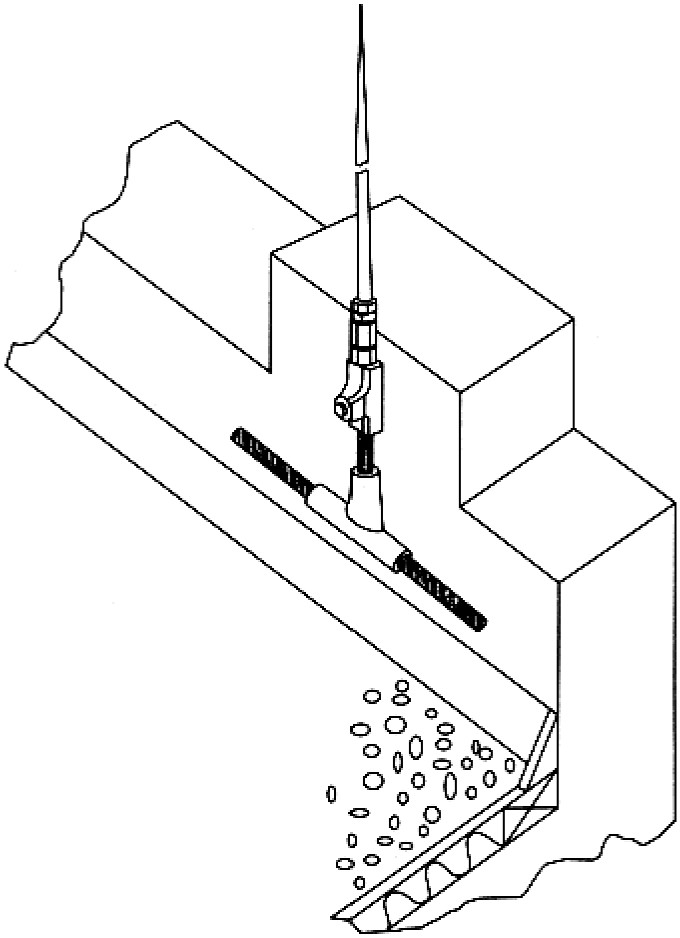


Figure 3-11.4(b) Irregular roof perimeter.

3-11.5 Open Areas in Flat Roofs.

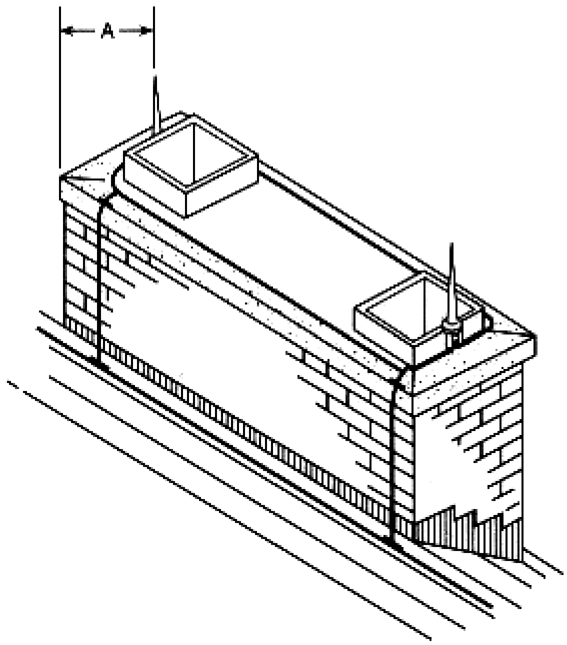
The perimeter of open areas, such as light or mechanical wells, that are located in large flat-roofed structures shall be protected if their perimeter exceeds 300 ft (92 m) provided both rectangular dimensions exceed 50 ft (15 m).

3-11.6 Domed or Rounded Roofs.

Air terminals shall be located as required so that no portion of the structure is located outside a zone of protection, based on a striking distance of 150 ft (45 m), as set forth in Section 3-11.

3-11.7 Chimneys and Vents.

Air terminals are required on all chimneys and vents, including metal chimneys having a metal thickness of less than $^{3}/_{16}$ in. (4.8 mm), where such chimneys or vents are not located within a zone of protection. If the metal thickness is $^{3}/_{16}$ in. (4.8 mm) or more, only a connection to the lightning protection system is required. Such a connection shall be made using a main size lightning conductor, a bonding device having a surface contact area of not less than 3 in.^{2} (1940 mm2), and shall provide a two-way path to ground as is required for air terminals. Required air terminals shall be installed on chimneys and vents so that the distance from an air terminal to an outside corner or the distance perpendicular to an outside edge shall be not greater than 2 ft (0.6 m). (*See Figure 3-11.7.*) Where only one air terminal is required on a chimney or vent, at least one main sized conductor shall connect the air terminal to a main conductor at the location where the chimney or vent meets the roof surface and provides a two-way path to ground from that location in accordance with Section 3-12 and 3-12.2.



A: 2 ft (0.6 m) maximum

Figure 3-11.7 Air terminals on chimney.

3-12 Conductors.

Conductors shall interconnect all air terminals and shall form a two-way path from each air terminal horizontally, downward, or rising at a rate not exceeding 3 in. per ft (76.2 mm) to connections with ground terminals, except as permitted by 3-12.1 and 3-12.2.

3-12.1 One-Way Path.

Air terminals on a lower roof level that are interconnected by a conductor run from a higher roof level only require one horizontal or downward path to ground provided the lower level roof conductor run does not exceed 40 ft (12 m).

3-12.2 Dead Ends.

Air terminals shall be permitted to be “dead ended” with only one path to a main conductor on roofs below the main protected level provided the conductor run from the air terminal to a main conductor is not more than 16 ft (4.9 m) in total length and maintains a horizontal or downward coursing. (*See Figure 3-12.2.*)

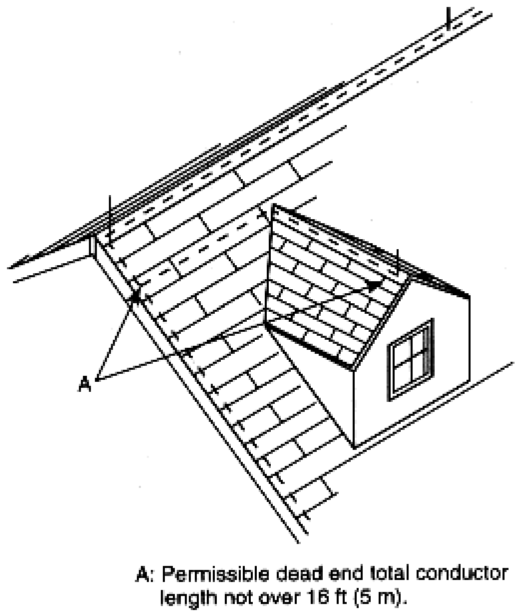


Figure 3-12.2 Dead end.

3-12.3 Substitution of Metals.

Metal parts of a structure, such as eave troughs, down spouts, ladders, chutes, or other metal parts shall not be substituted for the main lightning conductor. Likewise, metal roofing or siding having a thickness of less than $^{3}/_{16}$ in. (4.8 mm) shall not be substituted for main lightning conductors.

3-12.4 "U" or "V" Pockets.

Conductors shall maintain a horizontal or downward coursing free from "U" or "V" (down and up) pockets. Such pockets, often formed at low positioned chimneys, dormers, or other projections on sloped roofs, or at parapet walls, shall be provided with a down conductor from the base of the pocket to ground, or to an adjacent down-lead conductor. (*See Figure 3-12.4.*)

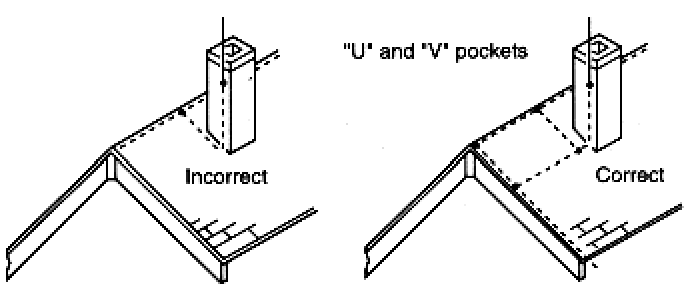


Figure 3-12.4 Pockets.

3-12.5 Conductor Bends.

No bend of a conductor shall form an included angle of less than 90 degrees, nor shall it have a radius of bend less than 8 in. (203 mm). (*See Figure 3-12.5.*)

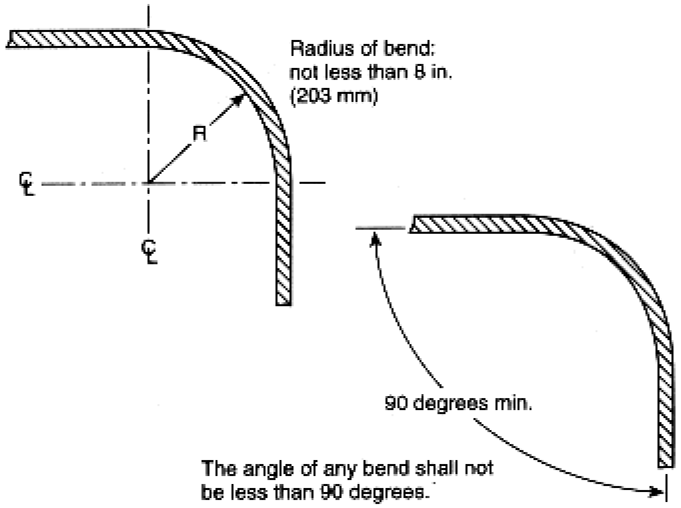


Figure 3-12.5 Conductor bends.

3-12.6 Conductor Supports.

Conductors shall be permitted to be coursed through air without support for a distance of 3 ft (0.9 m) or less. Conductors that must be coursed through air for longer distances shall be provided with a positive means of support that will prevent damage or displacement of the conductor.

3-12.7 Roof Conductors.

Roof conductors shall be coursed along ridges of gable, gambrel, and hip roofs, around the perimeter of flat roofs, behind or on top of parapets, and across flat or gently sloping roof areas as required to interconnect all air terminals. Conductors shall be coursed through or around obstructions (such as cupolas, ventilators, etc.) in a horizontal plane with the main conductor.

3-12.8 Cross-Run Conductors.

Cross-run conductors (main conductors) are required to interconnect the air terminals on flat or gently sloping roofs that exceed 50 ft (15 m) in width. For example, roofs from 50 ft (15 m) to 100 ft (30 m) in width require one cross run, roofs 100 ft (30 m) to 150 ft (46 m) in width require two cross runs, etc. Cross-run conductors shall be connected to the main perimeter cable at intervals not exceeding 150 ft (46 m).

3-12.9 Down Conductors.

Down conductors shall be as widely separated as practicable. Their location depends on such considerations as: the placement of air terminals, the most direct coursing of conductors, earth conditions, security against displacement, the location of large metallic bodies, and the location of underground metallic piping systems.

3-12.10 Number of Down Conductors.

At least two down conductors shall be provided on any kind of structure, including steeples. Structures exceeding 250 ft (76 m) in perimeter shall have a down conductor for every 100 ft (30 m) of perimeter or fraction thereof. The total number of down conductors on structures having flat or gently sloping roofs shall be such that the average distance between all down conductors does not exceed 100 ft (30 m). Irregular-shaped structures could require additional down conductors in order to provide a two-way path from each air terminal. For a flat or gently sloping roof structure, only the perimeter of the roof areas requiring protection shall be measured. When determining the perimeter of a pitched roof structure, the horizontal projection (footprint) of the protected roof shall be measured. Lower roofs or projections that are located within a zone of protection shall not be required to be included in the perimeter measurement. (*See Figure 3-12.10.*)

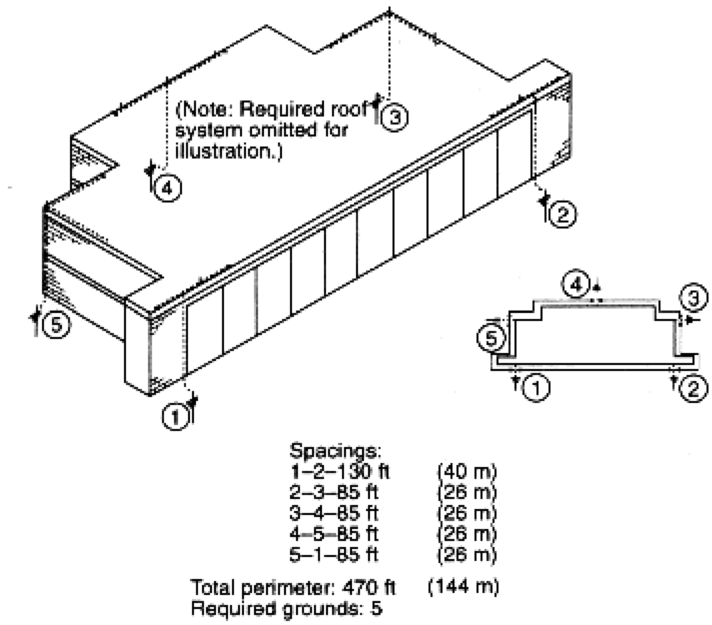


Figure 3-12.10 Quantity of down conductors.

3-12.11 Protecting Down Conductors.

Down conductors located in runways, driveways, school playgrounds, cattle yards, public walks, or other similar locations shall be guarded to prevent physical damage or displacement. If the conductor is run through ferrous metal tubing, the conductor shall be bonded to the top and bottom of the tubing. The down conductor shall be protected for a minimum distance of 6 ft (1.8 m) above grade level.

3-12.12 Down Conductor Entering Corrosive Soil.

Down conductors entering corrosive soil shall be protected against corrosion by a protective covering beginning at a point 3 ft (0.9 m) above grade level and extending for its entire length below grade.

3-12.13 Down Conductors and Structural Columns.

Down conductors coursed on or in reinforced concrete columns, or on structural steel columns shall be connected to the reinforcing steel or the structural steel member at its upper and lower extremities. In the case of long vertical members, an additional connection shall be made at intervals not exceeding 200 ft (60 m). Such connections shall be made using listed clamps or listed bonding plates, or by welding or brazing. The use of PVC conduit or other nonmetallic chase does not negate the need for these interconnections unless sufficient separation is provided to satisfy the bonding requirements of Sections 3-22, 3-23, and 3-24. Where such is not the case, provisions shall be made to assure the required interconnection of these parallel vertical paths.

3-13 Conductor Fasteners.

Conductors shall be securely fastened to the structure upon which they are placed, at intervals not exceeding 3 ft (1 m). The fasteners, attached by nails, screws, bolts, or adhesives as necessary, shall not be subject to breakage and shall be of the same material as the conductor, or of a material equally resistant to corrosion as that of the conductor. No combination of materials shall be used that forms an electrolytic couple of such nature that, in the presence of moisture, corrosion will be accelerated.

3-14 Masonry Anchors.

Masonry anchors used to secure lightning protection materials shall have a minimum outside diameter of $^1/_4$ in. (6.4 mm) and shall be set with care. Holes made to receive the body of the anchor shall be of the correct size, made with the proper tools, and preferably made in the brick, stone, or other masonry unit rather than in mortar joints. When the anchors are installed, the fit shall be tight against moisture thus reducing the possibility of damage due to freezing.

3-15 Connector Fittings.

Connector fittings shall be used at all “end-to-end,” “tee,” or “Y” splices of lightning conductors. They shall be attached so as to withstand a pull test of 200 lb (890 N). Fittings used for required connections to metal bodies in or on a structure shall be secured to the metal body by bolting, brazing, welding, or using high-compression connectors listed for the purpose. Conductor connections shall be of the bolted, welded, high compression, or crimp-type. Crimp-type connections shall not be used with Class II conductors.

3-16 Ground Terminals.

Each down conductor shall terminate at a ground terminal dedicated to the lightning protection system. The design, size, depth, and number of ground terminals used shall comply with 3-16.1 through 3-16.4.

3-16.1 Ground Rods.

Ground rods shall be not less than $^1/_2$ in. (12.7 mm) in diameter and 8 ft (2.4 m) long. Rods shall be copper-clad steel, solid copper, hot-dipped galvanized steel, or stainless steel. Rods shall be free of paint or other nonconductive coatings.

NOTE: Research has been presented that warns that stainless steel is very susceptible to corrosion in many soil conditions. Extreme caution should be used with proper soil analysis when this type of rod is used.

Electrical system and telecommunication grounding electrodes shall not be used in lieu of lightning ground rods. This provision shall not prohibit the required bonding together of grounding electrodes of different systems.

NOTE: For further information, see NFPA 70, *National Electrical Code*®, which contains detailed information on the grounding of electrical systems.

3-16.1.1 Ground Rod Terminations. The down conductor shall be attached to the ground rod by bolting, brazing, welding, or using high-compression connectors listed for the purpose. Clamps shall be suitable for direct soil burial.

3-16.1.2 Deep Moist Clay Soil. The lightning conductors or ground rods shall extend vertically not less than 10 ft (3 m) into the earth. The earth shall be compacted and made tight against the length of the conductor or ground rod. (*See Figure 3-16.1.2.*)

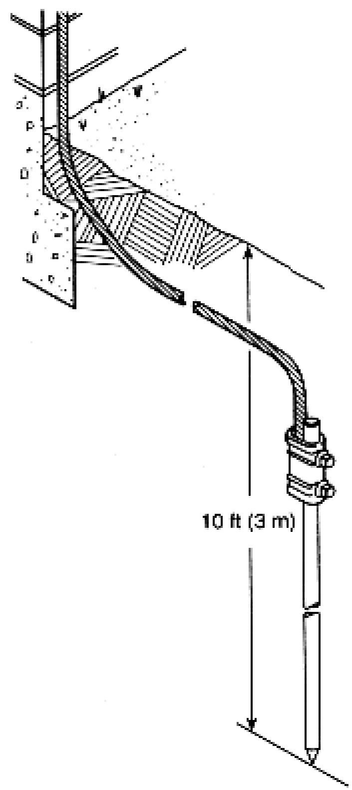


Figure 3-16.1.2 Grounding in moist clay-type soil.

3-16.1.3 Sandy or Gravelly Soil. In sand or gravel, two or more ground rods, at not less than 10 ft (3 m) spacings, shall be driven vertically to a minimum depth of 10 ft (3 m) below grade. (*See Figure 3-16.1.3.*)

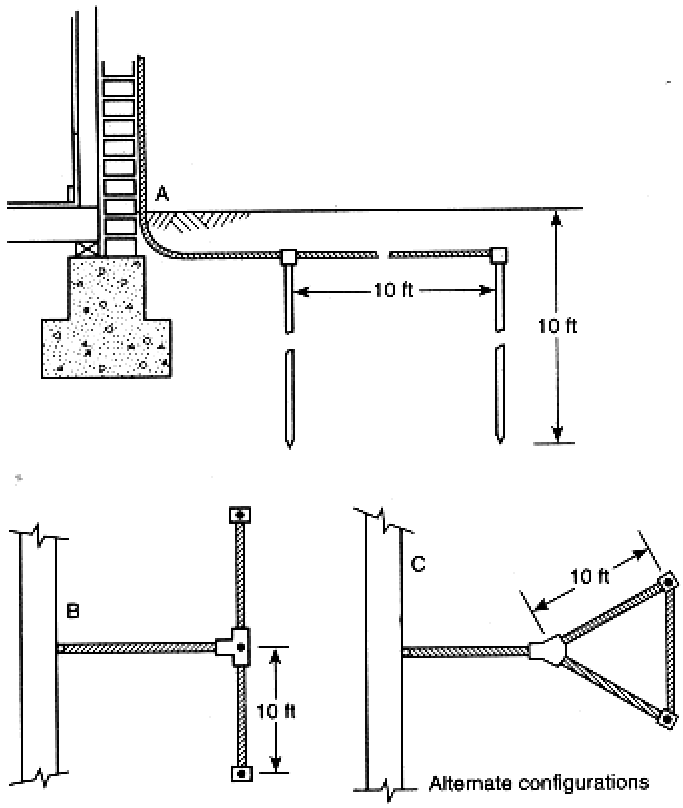


Figure 3-16.1.3 Grounding in sandy or gravelly soils.

3-16.1.4 Shallow Topsoil. Where bedrock is near the surface, the conductor shall be laid in trenches extending away from the building at each down conductor. These trenches shall be not less than 12 ft (3.7 m) in length and from 1 ft to 2 ft (0.3 m to 0.6 m) in depth in clay soil. In sandy or gravelly soil, the trench shall be not less than 24 ft (7.5 m) in length and 2 ft (0.6 m) in depth. If these methods should prove impractical, an acceptable alternative would be to carry the lightning protection cable in trenches of a depth specified above or, if this is impossible, directly on bedrock a minimum distance of 2 ft (0.6 m) from the foundation or exterior footing and terminate by attachment to a buried copper ground plate at least 0.032 in. (0.8 mm) thick and having a minimum surface area of 2 ft^2 (0.18 m^2).

3-16.1.5 Soil Less than 1 ft (0.3 m) Deep. If the soil is less than 1 ft (0.3 m) in depth, down conductors shall be connected to a loop conductor installed in a trench or in rock crevices around the structure. The loop conductor shall be not smaller than the equivalent of a main size lightning conductor. Optional plate electrodes may be attached to the loop conductor to enhance its earth contact where the measured grounding resistance is found to be too high to provide effective grounding. (*See Figure 3-16.1.5.*)

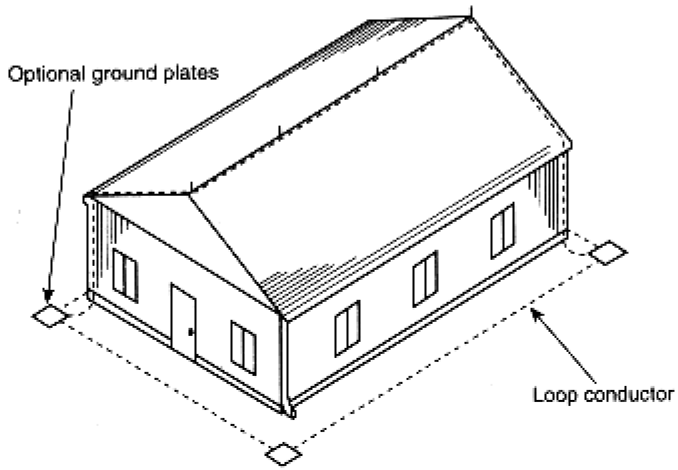


Figure 3-16.1.5 Grounding in soil less than 1 ft (0.3 m) deep.

3-16.2 Concrete Encased Electrodes.

Concrete encased electrodes shall only be used in new construction. The electrode shall be located near the bottom of a concrete foundation or footing that is in direct contact with the earth and shall be encased by not less than 2 in. (50.8 mm) of concrete. The encased electrode shall consist of:

(a) Not less than 20 ft (6.1 m) of bare copper main size conductor, or

(b) An electrode consisting of at least 20 ft (6.1 m) of one or more steel reinforcing bars or rods not less than $^{1}/_{2}$ in. (12.7 mm) in diameter that have been effectively bonded together by either welding or overlapping 20 diameters and securely wire-tying.

3-16.2.1 Concrete Encased Electrode Terminations. The down conductor(s) shall be permanently attached to the concrete encased electrode system by bolting, brazing, welding, or using high-compression connectors listed for the purpose.

3-16.3 Ground Ring Electrode.

A ground ring electrode encircling a structure shall be in direct contact with earth at a depth of not less than $2^{1}/_{2}$ ft (762 mm) or encased in a concrete footing in accordance with 3-16.2. It shall consist of not less than 20 continuous ft (6.1 m) of bare copper main size conductor.

3-16.3.1 Ground Ring Electrode Terminations. The down conductor(s) shall be permanently attached to the ground ring electrode by bolting, brazing, welding, or using high-compression connectors listed for the purpose. Clamps shall be suitable for direct burial.

3-16.4 Combinations.

Combinations of the above grounding terminals are permitted.

3-17 Common Grounding.

All grounding media in or on a structure shall be interconnected to provide a common ground potential. This shall include lightning protection, electric service, telephone and antenna system grounds, as well as underground metallic piping systems. Such piping systems include water service, well casings located within 25 ft (7.6 m) of the structure, gas piping, underground conduits, underground liquefied petroleum gas piping systems, etc. Interconnection to a gas line shall be made on the customer's side of the meter. Main size lightning conductors shall be used for interconnecting these grounding systems to the lightning protection system.

3-17.1 Common Ground Bondings.

If electric, telephone, or other systems are bonded to a metallic water pipe, only one connection from the lightning protection system to the water pipe system is required, provided that the water pipe is electrically continuous between all systems. If it is not electrically continuous, due to the use of plastic pipe sections or for other reasons, the nonconductive sections shall be bridged with main size conductors or the connection shall be made at a point where electrical continuity is assured.

3-18 Concealed Systems.

3-18.1 General.

Requirements covering exposed systems shall also apply to concealed systems, except conductors may be coursed under roofing materials, under roof framing, behind exterior wall facing, between wall studding, in conduit chases, or embedded directly in concrete or masonry construction. If a conductor is run in metal conduit, it shall be bonded to the conduit at the points where it enters and where it emerges from the conduit.

3-18.2 Masonry Chimneys.

Chimney air terminals and conductors shall be permitted to be concealed within masonry chimneys or to be attached to the exterior of masonry chimneys and routed through the structure to concealed main conductors.

3-18.3 Concealment in Steel Reinforced Concrete.

Conductors or other components of the lightning protection system concealed in steel reinforced concrete units shall be connected to the reinforcing steel. Concealed down conductors shall be connected to the vertical reinforcing steel in accordance with 3-12.13. Roof conductors or other concealed horizontal conductor runs shall be connected to the reinforcing steel at intervals not exceeding 100 ft (30 m).

3-18.4 Ground Terminals.

Ground terminals for concealed systems shall comply with Section 3-16. Ground terminals located under basement slabs or in crawl spaces shall be installed as near as practicable to the outside perimeter of the structure. Where rod or cable conductors are used for ground terminals, they shall be in contact with the earth for a minimum of 10 ft (3 m) and shall extend to a depth of not less than 10 ft (3 m) below finished grade, except as permitted by 3-16.3 and 3-16.4.

3-19 Structural Steel Systems.

3-19.1 General.

The structural steel framework of a structure shall be permitted to be utilized as the main conductor of a lightning protection system if it is electrically continuous or is made so.

3-19.2 Air Terminals.

Air terminals shall be connected to the structural steel framing by direct connection, by use of individual conductors routed through the roof or parapet walls to the steel framework, or by use of an exterior conductor that interconnects all air terminals and that is connected to the steel framework. Where such an exterior conductor is used, it shall be connected to the steel framework of the structure at intervals not exceeding 100 ft (30 m).

3-19.3 Connections to Framework.

Conductors shall be connected to areas of the structural steel framework, cleaned to base metal, by use of bonding plates having a surface contact area of not less than 8 in.^{2} (5200 mm^2) or by welding or brazing. Drilling and tapping the steel column to accept a threaded connector shall also be an acceptable method. The threaded device shall be installed with five threads fully engaged and secured with a jam-nut. The threaded portion of the connector shall be not less than $^1/_2$ in. (12.7 mm) in diameter. Bonding plates shall have bolt pressure cable connectors and shall be bolted, welded, or brazed securely to the structural steel framework so as to maintain electrical continuity. Where rust protective paint or coating is removed, the base steel shall be protected with a conductive, corrosion inhibiting coating.

3-19.4 Ground Terminals.

Ground terminals shall be connected to approximately every other steel column around the perimeter of the structure at intervals averaging not more than 60 ft (18 m). Connections shall be made near the base of the column in accordance with the requirements in 3-19.3.

3-19.5 Bonding Connections.

Where metal bodies located within a steel-framed structure are inherently bonded to the structure through the construction, separate bonding connections shall not be required.

3-20 Metal Antenna Masts and Supports.

Metal antenna masts or supports located on a protected structure shall be connected to the lightning protection system using main size conductors and listed fittings unless they are within a zone of protection.

3-21 Surge Suppression.

Devices suitable for protection of the structure shall be installed on electric and telephone service entrances and on radio and television antenna lead-ins.

NOTE: Electrical systems and utilization equipment within the structure can require further surge suppression. Such protection is not part of this standard. Documents such as ANSI/IEEE C-62.1, NFPA 70, *National Electrical Code* and UL 1449 provide additional information.

3-22 Metal Bodies.

Certain metal bodies located outside or inside a structure contribute to lightning hazards because they are grounded, or they assist in providing a path to ground for lightning currents. Such metal bodies shall be bonded to the lightning protection system in accordance with Sections 3-22, 3-23, and 3-24. (*See Appendix J for a technical discussion of lightning-protection potential-equalization bonding.*)

3-22.1 General.

In determining the necessity of bonding a metal body to a lightning protection system, the following factors shall be considered.

(a) Bonding is only required if there is likely to be a sideflash between the lightning protection system and another grounded metal body.

(b) The influence of a nongrounded metal body, such as a metal window frame in a nonconductive medium, is limited to its effectiveness as a short circuit conductor should a sideflash occur and, therefore, does not necessarily require bonding to the lightning protection system.

(c) Bonding distance requirements depend on a technical evaluation of the number of down conductors and their location, the interconnection of other grounded systems, the proximity of grounded metal bodies to the down conductors, and the flashover medium (i.e., air or solid materials).

(d) Metal bodies located in a steel-framed structure may be inherently bonded through construction and further bonding would not be required.

3-22.2 Materials.

Horizontal loop conductors used for the interconnection of lightning protection system downlead conductors, ground terminals, or other grounded media shall be sized no smaller than that required for the main lightning conductor. (*See Tables 3-4* and *3-5*.)

Conductors used for the bonding of grounded metal bodies, or isolated metal bodies, requiring connection to the lightning protection system shall be sized in accordance with bonding conductor requirements in Tables 3-4 and 3-5.

3-23 Potential Equalization.

3-23.1 Ground-Level Potential Equalization.

All grounded media in and on a structure shall be connected to the lightning protection system within 12 ft (3.6 m) of the base of the structure in accordance with Section 3-17.

For structures exceeding 60 ft (18 m) in height, the interconnection of the lightning protection system ground terminals, and other grounded media, shall be in the form of a ground loop conductor.

NOTE: For structures 60 ft (18 m) or less in height, a loop conductor should be provided for the interconnection of all ground terminals and other grounded media. Regardless of the building height, ground loop conductors should be installed underground in contact with earth. Ground-level potential equalization allows use of a ground ring electrode as a ground loop conductor. A ground ring electrode conforming to 3-16.3 shall be permitted to be utilized for the ground loop conductor.

3-23.2 Roof-Level Potential Equalization.

For structures exceeding 60 ft (18 m) in height, all grounded media in or on the structure shall be interconnected within 12 ft (3.6 m) of the main roof level.

NOTE: In the case of flat or gently sloping roofs, the roof conductors required by 3-12.7 shall be permitted to be used for achieving roof-level potential equalization. In the case of pitched roofs, the interconnection should be a loop placed at the eave level.

3-23.3 Intermediate-Level Potential Equalization.

Intermediate-level potential equalization is accomplished by the interconnection of the lightning protection system downlead conductors and other grounded media at the intermediate levels between the roof and the base of a structure in accordance with the following:

(a) *Steel-Framed Structures.* Intermediate-loop conductors are not required for steel-framed structures where the framing is electrically continuous.

(b) *Reinforced Concrete Structures where the Reinforcement Is Interconnected and Grounded in Accordance with 3-18.3.* The lightning protection system down-lead conductors and other grounded media shall be interconnected with a loop conductor at intermediate levels not exceeding 200 ft (60 m).

(c) *Other Structures.* The lightning protection down-lead conductors and other grounded media shall be interconnected with a loop conductor at intermediate levels not exceeding 60 ft (18 m).

3-24 Bonding of Metal Bodies.

3-24.1 Long, Vertical Metal Bodies.

(a) *Steel-Framed Structures.* Grounded and ungrounded metal bodies exceeding 60 ft (18 m) in vertical length shall be bonded to structural steel members as near as practical to their extremities unless inherently bonded through construction at these locations.

(b) *Reinforced Concrete Structures where the Reinforcement Is Interconnected and Grounded in Accordance with 3-18.3.*

Grounded and ungrounded metal bodies exceeding 60 ft (18 m) in vertical length shall be bonded to the lightning protection system as near as practical to their extremities, unless inherently bonded through construction at these locations.

(c) *Other Structures.* Bonding of grounded or ungrounded long, vertical metal bodies shall be determined by 3-24.2 and 3-24.3, respectively.

3-24.2 Grounded Metal Bodies.

This section covers the bonding of grounded metal bodies not covered in 3-24.1. Where grounded metal bodies have been connected to the lightning protection system at only one extremity, the following formula shall be used to determine if additional bonding is required. Branches of grounded metal bodies connected to the lightning protection system at their extremities shall require bonding to the lightning protection system in accordance with the following formula if they change vertical direction more than 12 ft (3.6 m).

NOTE: Where such bonding has been accomplished either inherently through construction or by physical contact between electrically conductive materials, no additional bonding connection is required.

(a) *Structures over 40 ft (12 m) in Height.* Grounded metal bodies shall be bonded to the lightning protection system where located within a distance “D” as determined by the formula:

$$D = \frac{h}{6n} \bullet K_m$$

Where “h” is the vertical distance between the bond being considered and the nearest lightning protection system bond.

The value of “n” is related to the number of down conductors that are spaced at least 25 ft (7.6 m) apart and located within a zone of 100 ft (30 m) from the bond in question and is calculated as follows:

1. Where bonding is required within 60 ft (18 m) from the top of any structure:

n = 1 where there is only one down conductor in this zone.

n = 1.5 where there are only two down conductors in this zone.

n = 2.25 where there are three or more down conductors in this zone.

K_m = 1.0 if the flashover is through air, or 0.50 if through dense material such as concrete, brick, wood, etc.

2. Where bonding is required below a level 60 ft (18 m) from the top of a structure, “n” is the total number of down conductors in the lightning protection system.

(b) *Structures 40 ft (12 m) and Less in Height.* Grounded metal bodies shall be bonded to the lightning protection system where located within a distance “D” as determined by the formula:

$$D = \frac{h}{6n} \bullet K_m$$

Where “h” is either the height of the building or the vertical distance from the nearest bonding connection from the grounded metal body to the lightning protection system and the point on the down conductor where the bonding connection is being considered.

The value of “n” is related to the number of down conductors that are spaced at least 25 ft (7.6 m) apart and located within a zone of 100 ft (30 m) from the bond in question and is calculated as follows:

n = 1 where there is only one down conductor in this zone.

n = 1.5 where there are only two down conductors in this zone.

n = 2.25 where there are three or more down conductors in this zone.

K_m = 1.0 if the flashover is through air, or 0.50 if through dense material such as concrete, brick, wood, etc.

3-24.3 Isolated (Nongrounded) Metallic Bodies.

An isolated metallic body, such as a metal window frame in a nonconducting medium, that is located close to a lightning conductor and to a grounded metal body will influence bonding requirements only if the total of the isolated distances between the lightning conductor and the isolated metal body, and between the isolated metal body and the grounded metal body is equal to or less than the calculated bonding distance. (*See Figure 3-24.3.*)

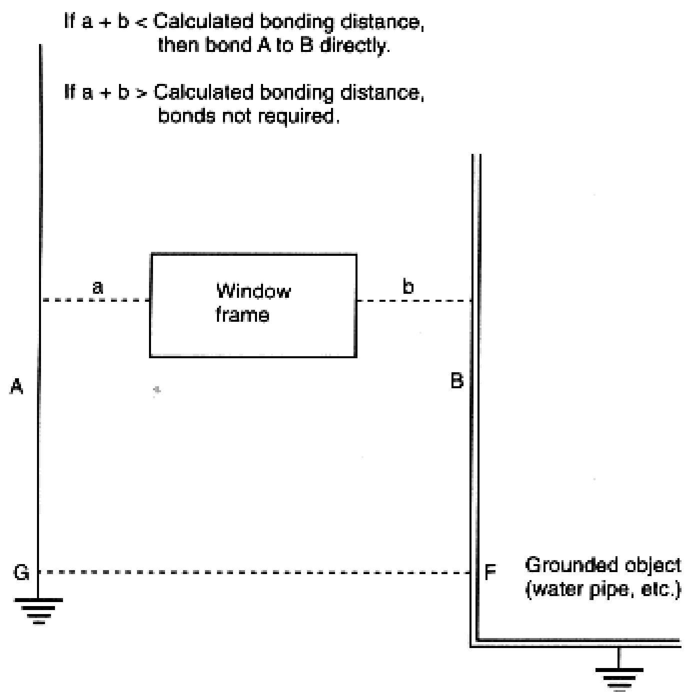


Figure 3-24.3 Effect of isolated (grounded) metallic bodies, such as window frame, in nonconductive media.

A bonding connection is required when the total of the shortest distance between the lightning conductor and the isolated metal body, and the shortest distance between the isolated metal body and the grounded metal body is equal to or less than the bonding distance as calculated in accordance with 3-24.2. Bondings shall be made between the lightning protection system and the grounded metal body and need not run through or be connected to the isolated metal body.

NOTE: In addition to the bonding of metal bodies, surge suppression should be provided to protect power, communication, and data lines from dangerous overvoltages and sparks caused by the lightning strikes. (*See Appendix J for a discussion of bonding and an understanding of problems often encountered.*)

Chapter 4 Protection for Miscellaneous Structures and Special Occupancies

4-1 General.

Special consideration shall be given to the miscellaneous structures and special occupancies covered in this chapter. All requirements of Chapter 3 shall apply except as modified.

4-2 Masts, Spires, Flagpoles.

These slender structures require one air terminal, down conductor, and ground terminal. Electrically continuous metal structures do not require air terminals or down conductors but do require ground terminals.

4-3 Grain, Coal, and Coke Handling and Processing Structures.

On wood frame elevators, provision shall be made to allow for the settling and rising of the structure as grain is loaded and unloaded.

4-4 Metal Towers and Tanks.

Metal towers and tanks constructed so as to receive a stroke of lightning without damage need only bonding to ground terminals as required in Chapter 3, except as provided in Chapter 6.

4-5 Air-Inflated Structures.

Air-inflated structures shall be protected with a mast-type or overhead ground wire-type system in accordance with Chapter 6, or with a lightning protection system in accordance with Chapter 3.

4-6 Concrete Tanks and Silos.

Lightning protection systems for concrete (including prestressed concrete) tanks containing flammable vapors, flammable gases, liquids that can produce flammable vapors, and concrete silos containing materials susceptible to dust explosions shall be provided with either external conductors or with conductors embedded in the concrete in accordance with Chapters 3 or 6.

Chapter 5 Protection for Heavy-Duty Stacks

5-1 General.

A smoke or vent stack is classified as heavy-duty if the cross-sectional area of the flue is greater than 500 in.^{2} (0.3 m^2) and the height is greater than 75 ft (23 m). (*See Figure 5-1.*)

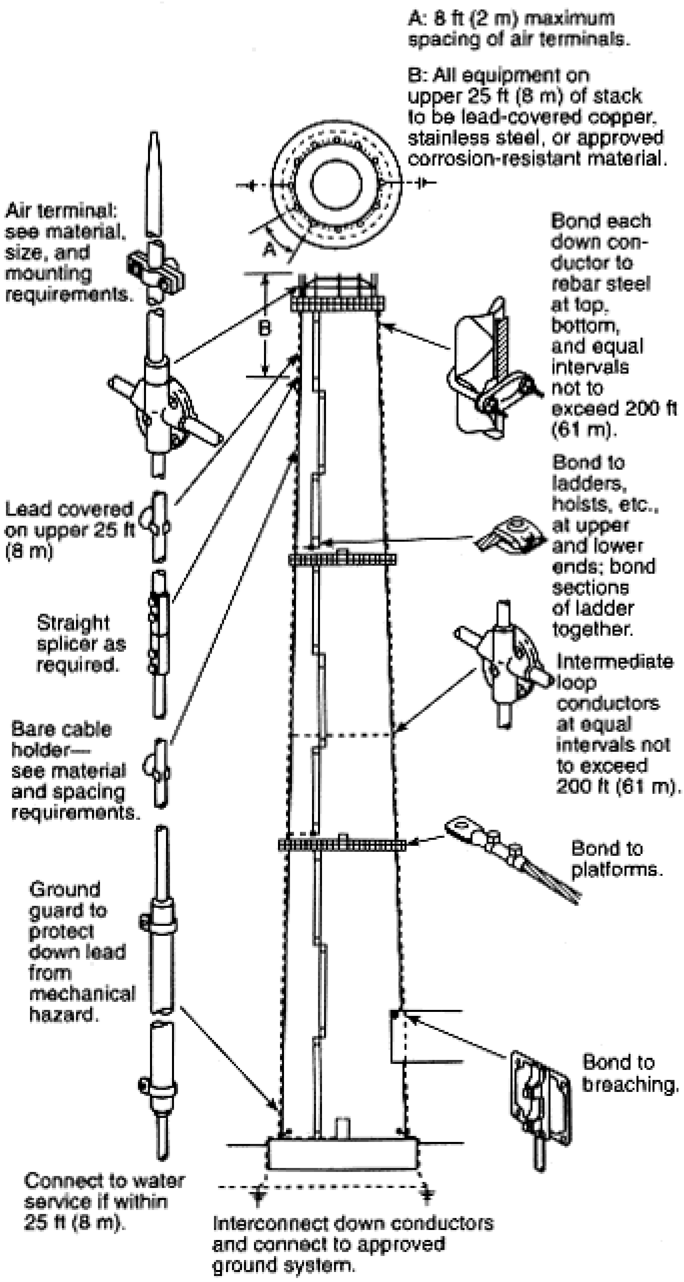


Figure 5-1 Heavy-duty stack.

5-2 Materials.

Materials shall be Class II as shown in Table 3-5, and as described in this chapter.

5-2.1 Corrosion Protection.

Copper and bronze materials used on the upper 25 ft (7.6 m) of a stack shall have a continuous covering of lead having minimum thickness of $^1/_{16}$ in. (1.6 mm) to resist corrosion by flue gases. Such materials include conductors, air terminals, connectors, splicers, and cable holders. Stacks that extend through a roof less than 25 ft (7.6 m) shall have a lead covering only on those materials above the roof level.

5-3 Air Terminals.

Air terminals shall be made of solid copper, stainless steel, or Monel Metal. They shall be located uniformly around the top of cylindrical stacks at intervals not exceeding 8 ft (2.4 m). On square or rectangular stacks, air terminals shall be located not more than 24 in. (600 mm) from the corners and shall be spaced not more than 8 ft (2.4 m) apart around the perimeter.

5-3.1 Air Terminal Heights.

The height of air terminals above the stacks shall be not less than 18 in. (460 mm) nor more than 30 in. (760 mm). They shall be at least $^5/_8$ in. (15 mm) in diameter, exclusive of the corrosion protection. Top-mounted air terminals shall not extend more than 18 in. (460 mm) above the top of the stack.

5-3.2 Air Terminal Mountings.

Air terminals shall be properly secured to the stack and shall be connected together at their lower end with a conductor forming a closed loop around the stack. Side-mounted air terminals shall be secured to the stack at not less than two locations. An anchored base connector shall be considered as one location.

5-3.3 Steel Hoods.

Stacks that have electrically continuous steel hoods covering the lining and column, and a metal thickness of not less than $^3/_{16}$ in. (4.8 mm), shall not require air terminals. The hood serves as a top loop conductor and shall be connected to each down conductor using a connection plate of not less than 8 in.^{2} (5200 mm^2) securely bolted or welded to the hood.

5-4 Conductors.

Conductors shall be copper, weighing not less than 375 lb per 1000 ft (558 g per m) without the lead covering. The size of any wire in the conductor shall be not less than 15 AWG.

5-4.1 Down Conductors.

Not less than two down conductors shall be provided. They shall be located on opposite sides of the stack and lead from the loop conductor at the top to ground terminals. Down conductors shall be interconnected within 12 ft (3.6 m) of the base by a loop conductor, preferably below grade. The down conductor shall also be interconnected with a loop conductor at approximately equal intervals not to exceed 200 ft (67 m). Down conductors shall be protected from physical damage or displacement for a distance of not less than 8 ft (2.4 m) above grade.

5-5 Fasteners.

Fasteners shall be of copper, bronze, or stainless steel. They shall be anchored firmly to the stack by masonry anchors or lay-in attachments. The threaded shank of fasteners shall be not less than $^1/_2$-in. (13-mm) diameter for air terminals and $^3/_8$-in. (10-mm) diameter for conductors. Vertical conductors shall be fastened at intervals not exceeding 4 ft (1.2 m) and horizontal conductors at intervals not exceeding 2 ft (0.6 m).

5-6 Splices.

Splices in conductors shall be as few as practicable and shall be attached so as to withstand a pull test of 200 lb (890 N). All connections and splices shall be by bolting, brazing, welding, or using high-compression connectors listed for the purpose. All connectors and splicers shall make contact with the conductor for a distance not less than $1^1/_2$ in. (38 mm), measured parallel to the axis of the conductor.

5-7 Reinforced Concrete Stacks.

All reinforcing steel shall be made electrically continuous and bonded to each down conductor within 12 ft (3.6 m) of the top and base of the stack and at approximately equal intervals not to exceed 200 ft (67 m). Tying or clipping of reinforcing steel shall be an acceptable means of ensuring continuity. Clamps or welding shall be used for all connections to the reinforcing steel and to the down conductors.

5-8 Bonding of Metal Bodies.

Bonding of metal bodies on a heavy-duty stack shall comply with the requirements of Sections 3-22, 3-23, and 3-24 and as described herein.

5-8.1 Potential Equalization.

(a) *Ground Level of Stack.* All interior and exterior grounded media shall be interconnected by a loop conductor within 12 ft (3.6 m) of the base of the stack. This shall include, but not be limited to, lightning protection down conductors, conduit, piping, elevators, ladders, and breeching steel and reinforcing steel.

(b) *Top Level of Stack.* All interior and exterior grounded media shall be interconnected within 12 ft (3.6 m) of the top of the stack.

(c) *Intermediate Levels of Stack.* All interior and exterior vertical grounded media shall be interconnected at approximately equal intervals not to exceed 200 ft (67 m).

5-8.2 Isolated (Nongrounded) Protruding Metal Bodies.

(a) Isolated protruding metal bodies 150 ft (50 m) or more above the base and on the exterior of a stack are subject to a direct strike and shall be interconnected to the lightning protection system. These shall include, but not be limited to, rest platforms, jib hoists, and other metal bodies protruding 18 in. (460 mm) or more from the column wall.

(b) Isolated metal bodies on the interior of a reinforced steel stack, or within the zone of protection on the exterior shall not be required to be connected to the lightning protection system.

5-9* Grounding.

A ground terminal, suitable for the soil conditions encountered, shall be provided for each down conductor. Ground terminals shall be in accordance with Section 3-16, except ground rods shall be a copper-clad or stainless steel rod having a diameter of not less than $^5/_8$ in. (15.9 mm) and shall be at least 10 ft (3 m) in length.

5-10 Metal Stacks.

Heavy-duty metal stacks having a metal thickness of $^{3}/_{16}$ in. (4.8 mm) or greater do not require air terminals or down conductors. They shall be grounded by means of at least two ground terminals located on opposite sides of the stack. If the stack is an adjunct of a building or located within the sideflash distance as determined by Sections 3-22, 3-23, and 3-24, it shall be interconnected to the lightning protection on the building. If the stack is located within the perimeter of a protected building, two connections shall be made between the stack conductors and the nearest main building lightning conductors at or about the roof level.

5-10.1 Metal Guy Wires and Cables.

Metal guy wires and cables used to support metal stacks shall be grounded at their lower ends if anchored in concrete, or to a building or other nonconductive support.

Chapter 6 Protection for Structures Containing Flammable Vapors, Flammable Gases, or Liquids that Can Give Off Flammable Vapors

6-1 Reduction of Damage.

6-1.1*

This chapter applies to the protection of structures containing flammable vapors, flammable gases, or liquids that can give off flammable vapors. For the purpose of this chapter, the term “structure” shall apply to the vessel, tank, or other container in which this material is contained.

6-1.2

Certain types of structures used for the storage of liquids that can produce flammable vapors, or used to store flammable gases are essentially self-protecting against damage from lightning strokes and need no additional protection. Metallic structures that are electrically continuous, tightly sealed to prevent the escape of liquids, vapors, or gases, and of adequate thickness to withstand direct strokes in accordance with 6-3.2 are inherently self-protecting. Protection of other structures may be achieved by the use of air terminals, masts, overhead ground wires, or other types of protective devices.

6-1.3

Chapters 3 through 5 of this standard give requirements for the protection of buildings and miscellaneous property against lightning damage. Because of the nature of the contents of the structures considered in this chapter, extra precautions shall be taken. In these structures, a spark that would otherwise cause little or no damage might ignite the flammable contents and result in a fire or explosion.

6-2 Fundamental Principles of Protection.

Protection of these structures and their contents from lightning damage requires adherence to the following principles:

(a) Liquids that can give off flammable vapors shall be stored in essentially gastight structures.

(b) Openings where flammable concentrations of vapor or gas can escape to the atmosphere shall be closed or otherwise protected against the entrance of flame.

(c) Structures and all appurtenances (e.g., gauge hatches, vent valves) shall be maintained in good operating condition.

(d) Flammable air-vapor mixtures shall be prevented, to the greatest possible extent, from accumulating outside of such structures.

(e) Potential spark gaps between metallic conductors shall be avoided at points where flammable vapors may escape or accumulate.

6-3 Protective Measures.

6-3.1 Materials and Installation.

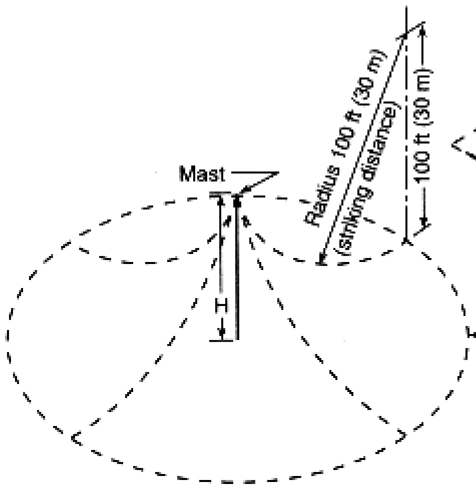
Conductors, air terminals, and grounding connections shall be selected and installed in accordance with the requirements of Chapter 3 and as described in this chapter. Overhead ground wires shall be noncorrosive for the conditions existing at the site. The overhead ground wire selected shall be sized to be equivalent in cross-sectional area to a main conductor and shall be self-supporting with minimum sag under all conditions. It shall be constructed of materials such as aluminum, copper, copper- or aluminum-clad steel, lead or galvanized steel, or stainless steel.

6-3.2 Sheet Steel.

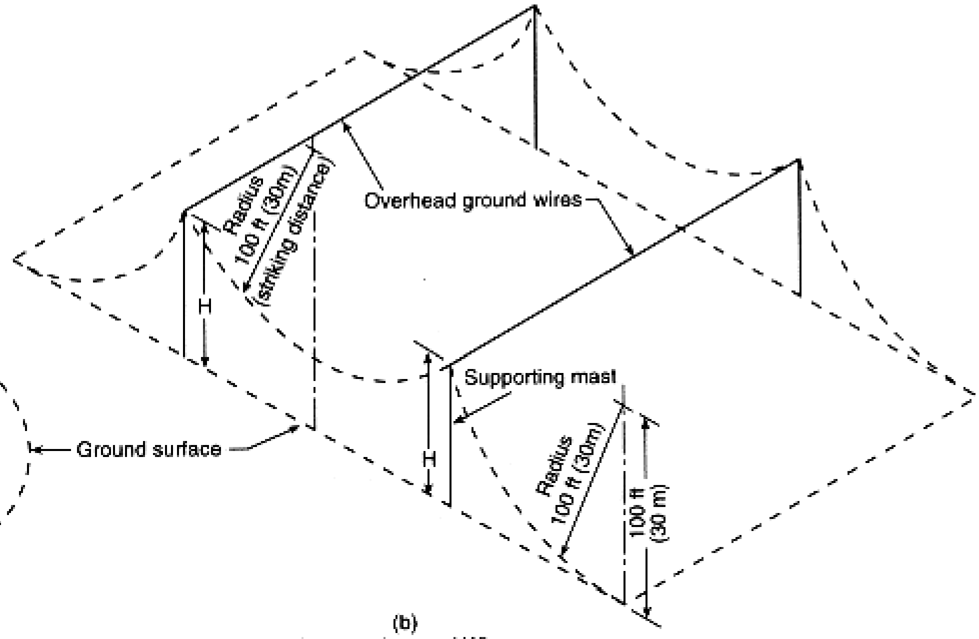
Sheet steel less than $^{3}/_{16}$ in. (4.8 mm) in thickness might be punctured by severe strokes and shall not be relied upon as protection from direct lightning strokes.

6-3.3 Rods, Masts, and Overhead Ground Wires.

6-3.3.1 The zone of protection of a lightning protection mast is based on the striking distance of the lightning stroke (the distance over which final breakdown of the initial stroke to ground, or to a grounded object, occurs). Since the lightning stroke may strike any grounded object within the striking distance of the point from which final breakdown to ground occurs, the zone of protection is defined by a circular arc concave upward. [*See Figure 6-3.3.1(a).*] The radius of the arc is the striking distance, and the arc passes through the tip of the mast and is tangent to the ground. Where more than one mast is used, the arc passes through the tips of adjacent masts. [*See Figures 6-3.3.1(b) and 6-3.3.1(c).*]

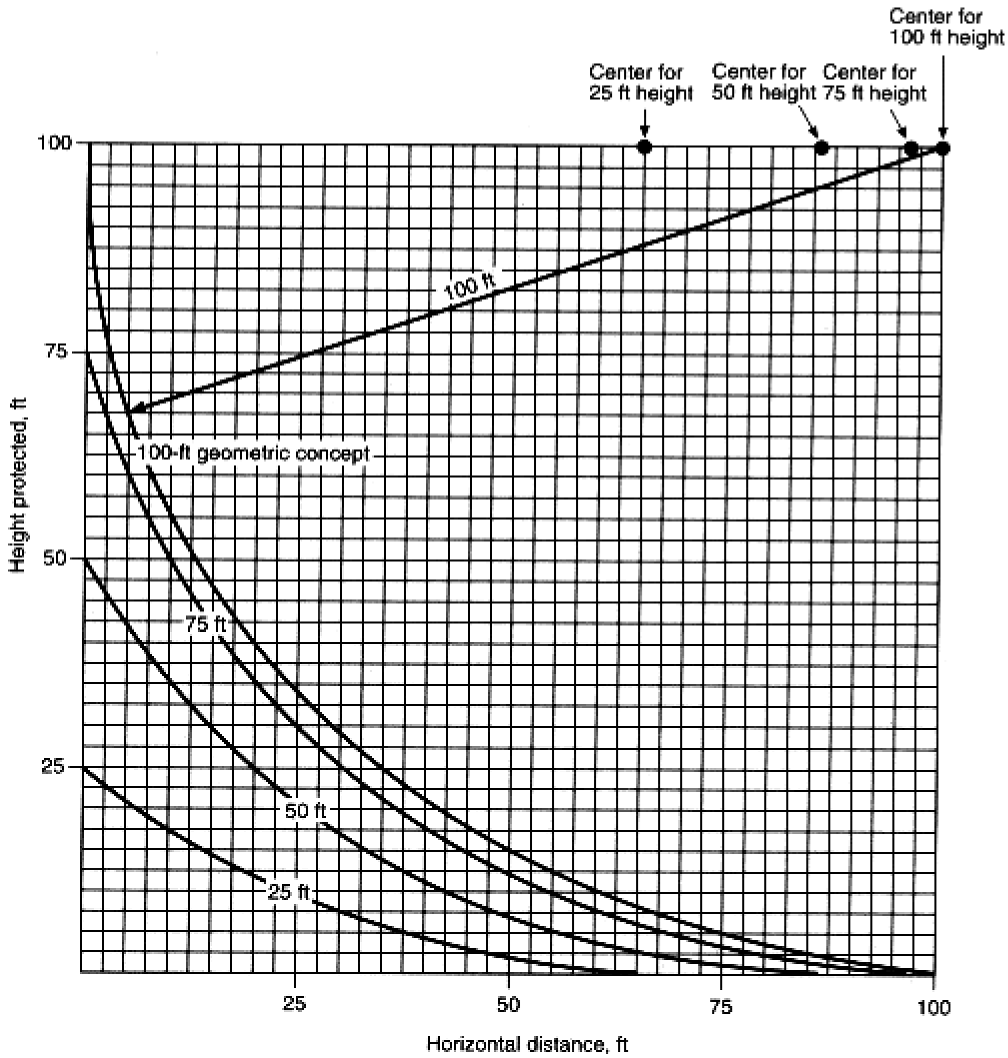


(a)
Single mast
Zone of protection defined by dashed lines.



(b)
Overhead ground Wires
Zone of protection defined by ground wire(s)
and dashed lines.

Figure 6-3.3.1(a) Single mast zone of protection. **Figure 6-3.3.1(b) Overhead ground wires.**



Note: The distance can be determined analytically for a 100 ft (30 m) striking distance with the following equation:

$$d = \sqrt{h_1 (200 - h_1)} - \sqrt{h_2 (200 - h_2)}$$

where: d = horizontal distance, ft
h_1 = height of higher mast, ft
h_2 = height of lower mast, ft
SI units : 1 ft = 0.30 m

Figure 6-3.3.1(c) Zone of protection 100-ft (30-m) striking distance.

The striking distance is related to the peak stroke current and thus to the severity of the lightning stroke; the greater the severity of the stroke, the greater the striking distance. In the vast majority of cases, the striking distance exceeds 100 ft (30 m). Accordingly, the zone based on a striking distance of 100 ft (30 m) is considered to be adequately protected.

The zone of protection afforded by any configuration of masts or other elevated, conductive grounded objects can readily be determined graphically. Increasing the height of a mast above the striking distance will not increase the zone of protection.

6-3.3.2 The zone of protection of an overhead ground wire is based on a striking distance of 100 ft (30 m) and is defined by 100-ft (30-m) radius arcs concave upward. [*See Figure 6-3.3.1(b).*] The supporting masts shall have a clearance from the protected structure as under 6-3.3.3.

6-3.3.3 To prevent sideflashes, the minimum distance between a mast or overhead ground wire and the structure to be protected shall be not less than the bonding distance or sideflash distance. Sideflash distance from a mast can be calculated from the formula

$$D = \frac{h}{6}$$

Where:

h =height of structure (or object under consideration).

Sideflash distance from a catenary can be calculated as

$$D = \frac{l}{6n}$$

Where:

l = length of lightning protection cable between its grounded point and the point under consideration.

n = 1 where there is a single overhead conductor that exceeds 200 ft (67 m) in horizontal length.

n = 1.5 where there is a single overhead wire or more than one wire interconnected above the structure to be protected, such that only two down conductors are located greater than 20 ft (6 m)and less then 100 ft apart.

n = 2.25 where there are more than two down conductors spaced more than 25 ft (7.6 m) apart within a 100-ft (30-m) wide area that are interconnected above the structure being protected.

The masts or overhead ground wires shall be grounded and interconnected with the grounding system of the structure to be protected. The grounding requirements of Chapter 3 shall apply.

6-3.3.4 Masts of wood, used either separately or with ground wires, shall have an air terminal extending at least 2 ft (0.6 m) above the top of the pole, securely attached to the pole (*see Figure 6-3.3.4*), and connected to the grounding system. As an alternative, an overhead ground wire or a down conductor, extending above or across the top of the pole, can be used as the air terminal. In case of an overhead ground-wire system, the pole guy wire can be used as the down conductor. (*See Figure 6-3.3.4.*) For metallic masts, the air terminal and the down conductor shall not be required.

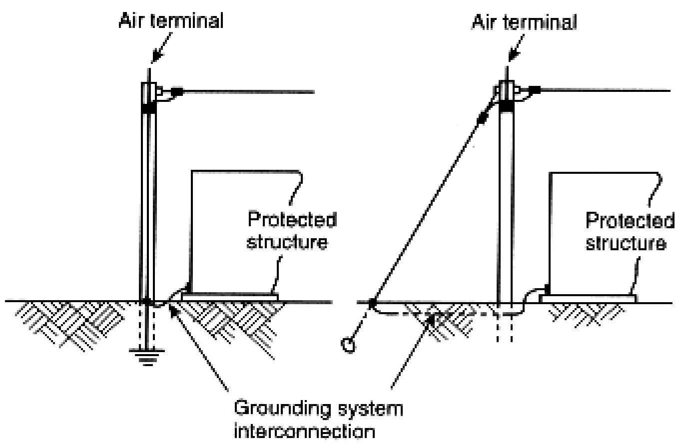


Figure 6-3.3.4 Alternate grounding method for overhead ground-wire protection.

6-4 Protection of Specific Classes of Structures.

6-4.1 Aboveground Tanks at Atmospheric Pressure Containing Flammable Vapors or Liquids that Can Give Off Flammable Vapors.

6-4.1.1 Fixed Roof Tanks. Metallic tanks with steel roofs of riveted, bolted, or welded construction, with or without supporting members, used for the storage of liquids that give off flammable vapors at atmospheric pressure are considered to be protected against lightning (inherently self-protecting) if the following requirements are met:

(a) All joints between metallic plates shall be riveted, bolted, or welded.

(b) All pipes entering the tank shall be metallically connected to the tank at the point of entrance.

(c) All vapor or gas openings shall be closed or provided with flame protection where the stored stock might produce a flammable air-vapor mixture under storage conditions.

(d) The roof shall have a minimum thickness of $^{3}/_{16}$ in. (4.8 mm).

(e) The roof shall be welded, bolted, or riveted to the shell.

6-4.1.2 Floating Roof Tanks.

(a) *General.* Fires have occurred when lightning has struck the rims of open-top floating roof tanks where the roofs were quite high and the contents volatile. Similar above-the-seal fires have occurred when direct lightning strokes to the rims of floating roof tanks have ignited flammable vapors within the open shells. These have occurred where roofs were low. The resulting seal fires have been at small leakage points in the seal. An effective defense against ignition by a direct stroke is a tight seal.

Fires have also occurred in the seal space of open-top floating roof tanks as a result of lightning-caused discharges. These have occurred most frequently in tanks having floating roofs and seals with vapor spaces below the flexible membranes. Similar vapor spaces will be formed where tanks are fitted with secondary seals in compliance with environmental regulations. Ignition can be from a direct stroke or from the sudden discharge of an induced (bound) charge on the floating roof, released when the charge on a cloud discharges to ground or to another cloud.

(b) *Protection.* Where floating roofs utilize hangers located within a vapor space, the roof shall be electrically bonded to the shoes of the seal through the most direct electrical path at intervals not greater than 10 ft (3 m) on the circumference of the tank. These shunts shall consist of flexible Type 302, 28-gauge [$^1/_{64}$ in. × 2 in. (0.4 mm × 51 mm)] wide stainless steel straps, or the equivalent in current-carrying capacity and corrosion resistance. The metallic shoe shall be maintained in contact with the shell and without openings (such as corrosion holes) through the shoe. Tanks without a vapor space at the seal do not require shunts at the seal. Where metallic weather shields cover the seal, they shall maintain contact with the shell.

Where a floating roof is equipped with both primary and secondary seals, the space between the two seals might contain a vapor-air mixture within the flammable range. If the design of such a seal system incorporates electrically conductive materials and a spark gap exists within that space, or could be created by roof movement, shunts shall be installed so that they directly contact the tank shell above the secondary seal. The shunts shall be spaced at intervals not greater than 10 ft (3 m) and shall be constructed so that metallic contact is maintained between the floating roof and the tank shell in all operational positions of the floating roof.

6-4.1.3 Metallic Tanks with Nonmetallic Roofs. Metallic tanks with wooden or other nonmetallic roofs are not considered to be self-protecting, even if the roof is essentially gastight and sheathed with thin metal and with all gas openings provided with flame protection. Such tanks shall be provided with air terminals. Such air terminals shall be bonded to each other, to the metallic sheathing, if any, and to the tank shell. Isolated metal parts shall be bonded as provided in Section 3-22. In lieu of air terminals, any of the following may be used: conducting masts, overhead ground wires, or a combination of masts and overhead ground wires.

6-4.1.4 Grounding Tanks. Tanks shall be grounded to conduct away the current of direct strokes and to avoid the buildup and potential that might cause sparks to ground. A metal tank shall be grounded by one of the following methods:

(a) A tank is connected without insulated joints to a grounded metallic piping system.

(b) A vertical cylindrical tank rests on earth or concrete and is at least 20 ft (6 m) in diameter, or rests on bituminous pavement and is at least 50 ft (15 m) in diameter.

(c) By bonding the tank to ground through a minimum of two ground terminals, as described in Section 3-16, at maximum 100-ft (30-m) intervals along the perimeter of the tank. This also applies to tanks with an insulating membrane beneath the tank.

6-4.2 Earthen Containers at Atmospheric Pressure Containing Flammable Vapors or Liquids that Can Give Off Flammable Vapors.

Earthen containers enclosing flammable vapors or liquids that can give off flammable vapors, lined or unlined, having combustible roofs shall be protected by air terminals, separate masts, overhead ground wires, or a combination of these devices.

6-4.3

Above ground nonmetallic tanks shall be protected as described in 6-3.3.

Chapter 7 Protection for Watercraft

7-l General. The intent of this chapter is to provide lightning protection requirements for watercraft while in water. Lightning protection systems installed on watercraft shall be installed in accordance with the provisions of this chapter.

NOTE 1: A lightning protection system installed in accordance with the requirements of this chapter offers no protection for a watercraft that is out of the water.

NOTE 2: Personnel on small watercraft shall exit the water as quickly as practical when an approaching thunderstorm is noticed. (*See Appendix C for information on personnel safety.*)

NOTE 3: A lightning protection system is not intended to afford protection if any part of the watercraft contacts a power line or other voltage source while in water or on shore.

7-2 Materials.

7-2.1

The materials used in the lightning protection system shall be resistant to corrosion. The use of combinations of metals that form detrimental galvanic couples shall be avoided.

7-2.2

In those cases where it is impractical to avoid a junction of dissimilar metals, the corrosion effect shall be permitted to be reduced by the use of suitable plating or special connectors, such as stainless steel connectors used between aluminum and copper alloys.

Exception: Except for the use of conducting materials that are part of the structure of the watercraft, such as aluminum masts, only copper shall be used in a lightning conductor system. All copper conductors shall be the grade ordinarily required for commercial electrical work, which generally is designated as providing 98-percent conductivity where annealed.

7-2.3 Copper Conductors.

Copper cable conductors shall be of a diameter not less than No. 4 AWG (41,740 CM) for the main down conductor, not less than No. 6 AWG for two parallel paths, or No. 8 AWG for more than two paths (such as those to shrouds and stay connections on sailboats). The thickness of any copper ribbon or strip (except for grounding plates and strips as discussed in 7-5.1) shall not be less than No. 20 AWG. Where other materials are used, the gauge shall be such as to provide conductivity equal to or greater than the required conductor size.

NOTE: See NFPA 302, *Fire Protection Standard for Pleasure and Commercial Motor Craft,* Table 7-12.5 for minimum strand sizes for watercraft conductors.

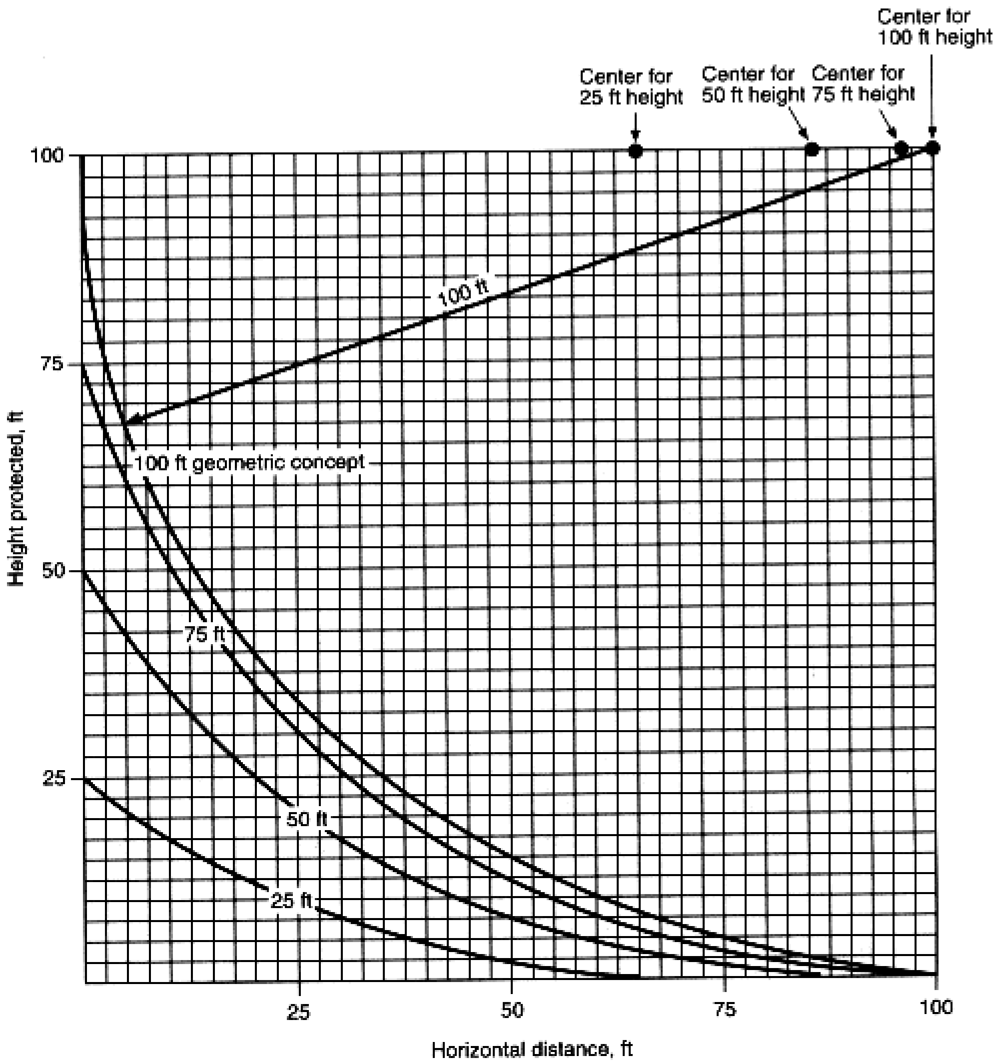
7-2.4 Joints.

Joints shall be mechanically strong and shall be made such that they do not have an electrical resistance in excess of that of 2 ft (0.610 m) of conductor.

7-3 Antennas, Masts, and Overhead Ground Wires.

7-3.1 General.

The zone of protection for watercraft is based on a striking distance of 100 ft. The zone of protection afforded by any configuration of masts or other elevated conductive objects can be readily determined graphically or mathematically as shown in Figure 7-3.1(a). Figure 7-3.1(b) provides an example of how the zone of protection is to be determined for a watercraft with multiple masts.



Note: The distance can be determined analytically for a 100 ft (30 m) striking distance with the following equation:

$$d = \sqrt{h_1 (200 - h_1)} - \sqrt{h_2 (200 - h_2)}$$

where: d = horizontal distance, ft
h_1 = height of air terminal, ft
h_2 = height of object to be protected, ft
For SI units : 1 ft = 0.305 m

Figure 7-3.1(a) Zone of protection 100 ft (30 m) striking distance.

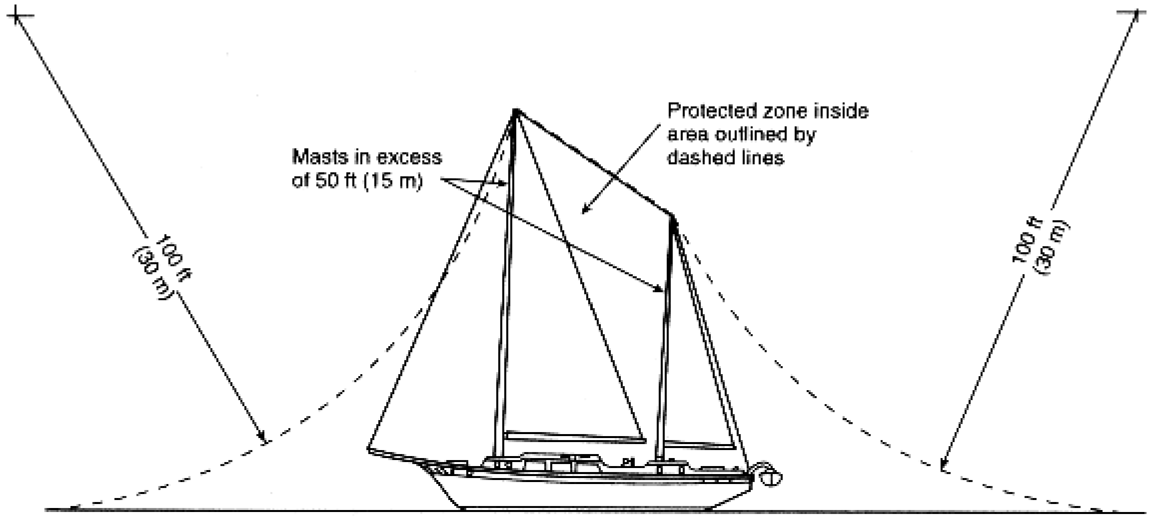


Figure 7-3.1(b) Diagram of boat with masts in excess of 50 ft (15 m) above the water-protection based on lightning strike distance of 100 ft (30 m).

7-3.2 Air Terminals.

Air terminals (including conductive masts, etc.) meeting the requirements of Section 3-9 shall be so located and of sufficient height to provide a zone of protection that covers the entire watercraft. They shall be mechanically strong to withstand the roll and pitching action of the hull as well as heavy weather. The air terminal shall be permitted to be raked at an angle but shall be substantially vertical.

7-3.3 Metallic Masts.

A metallic mast used as an air terminal shall have a conductivity equivalent to a No. 4 AWG copper conductor. They shall be grounded in accordance with the requirements provided in Sections 7-4 and 7-5.

7-3.4 Nonmetallic Masts.

A nonmetallic mast not within the zone of protection of an air terminal shall be provided with an air terminal as described in Section 3-9. The air terminal shall extend a minimum of 6 in. (152 mm) above the mast. The air terminal shall be provided with a copper conductor or strip securely fastened to the mast. The down conductor shall have a conductivity equivalent to a No. 4 AWG copper conductor. A grounding system meeting the requirements of Section 7-5 shall also be provided.

7-3.5 Radio Antennas.

A solid metal vertical radio antenna shall be permitted to serve as an air terminal for small nonmetallic watercraft, provided a provision is made to ground the metal antenna with a conductor equivalent to a No. 4 AWG copper conductor. The conductor shall be routed vertically to the lightning grounding plate, the lightning grounding strip under the watercraft, or to an equalization bus. The height of the antenna shall be sufficient to provide the required zone of protection for the watercraft and its occupants.

Because a loading coil presents a high impedance to the flow of lightning currents, the coil shall be shorted, equipped with a surge suppression device (lightning arrester) for bypassing the lightning current or grounded above the coil.

Nonmetallic radio antennas with spirally wrapped conductors shall not be used for lightning protection.

7-3.6 Temporary Air Terminal.

On small watercraft that cannot be equipped with a permanent air terminal, a temporary air terminal shall be permitted. The temporary air terminal shall be located so as to provide a zone of protection covering the entire watercraft and its occupants when installed. Temporary air terminals shall have a conductivity equivalent to a No. 4 AWG copper conductor.

Exception: A solid stainless steel whip antenna or equivalent shall be permitted to be used as a temporary air terminal.*

The location of the air terminal base shall be such that persons on the watercraft can avoid physical contact with the air terminal or its base.

7-4 Conductors.

7-4.1 Lightning Grounding Conductors.

Lightning grounding conductors shall be routed directly to a ground, as discussed in Section 7-5, to the maximum extent practicable (minimizing bends, etc.). Lightning grounding conductors also shall be routed as remotely as possible from the watercraft's wiring to minimize sideflashes and to avoid introducing high voltages into the watercraft's wiring system. The watercraft wiring system shall be routed perpendicular to the lightning grounding conductors where practicable.

7-4.2* Interconnecting Conductors.

An interconnecting conductor, equivalent to No. 8 AWG copper conductor, shall be provided at all locations where sideflashes are likely to occur. Large metallic masses that are subject to sideflashes shall be connected to the lightning grounding plate(s), the lightning grounding strip, or to the equalization bus, if provided, in accordance with Section 7-6.

7-4.3 Metallic Tanks.

Metallic tanks shall be connected directly to the lightning ground plate(s), the lightning grounding strip, or to the equalization bus.

7-4.4 Shrouds and Stays.

Shrouds and stays shall be permitted as part of the path to ground from the air termination point on the mast to the lightning grounding plate or strip. The aggregate conductivity and inductance, including the mast, shall be not less than that of a No. 4 AWG copper conductor. Where stainless steel shrouds and stays are used in the lightning protection system, every shroud or stay shall be connected at its lower end or at the chainplates directly to the lightning grounding plate or lightning grounding strip with conductors having the minimum size of a No. 8 AWG copper conductor.

Stainless steel shrouds of small diameter and stays on small sailboats that are trailered which do not have the required conductivity (less than that of a No. 8 AWG copper conductor) shall be grounded at their lower ends in addition to the grounding of the mast. The mast shall serve as the primary lightning conductor.

7-5 Grounding.

7-5.1 Watercraft with Metal Hulls.

If an electrical connection exists between a metallic hull and a lightning air terminal or other metallic superstructure of sufficient height to provide the zone of protection specified in Section 7-3, no further protection shall be necessary; however, surge suppression in accordance with Section 3-21 shall be provided. Conducting objects projecting above metal masts or superstructures shall be grounded with a grounding conductor connected to the metal hull or superstructure.

7-5.2 Watercraft with Nonmetallic Hulls.

Grounding plates or strips shall be installed on the underside of the hull of nonmetallic watercraft to provide a path for the lightning current into the water.

7-5.2.1 Grounding Plate. A grounding plate of copper, copper alloys, or stainless steel shall be provided. The plate shall have a minimum size of 1 $ft^2 \times {}^3/_{16}$-in. (0.09 $m^2 \times$ 4.8-mm) thick. It shall be located as closely as possible below the lightning air terminal. Through-hull connectors shall be metallic and have a cross-sectional area equivalent to a No. 4 AWG copper conductor.

7-5.2.2 Grounding Strip. An external grounding strip of copper, copper alloys, or stainless steel installed under the watercraft running fore and aft, shall have a minimum thickness of ${}^3/_{16}$ in. (4.8 mm) and a minimum width of ${}^3/_4$ in. (l9 mm). The length of the strip shall be permitted to extend from a point located directly below the lightning protection air terminal to the aft end of the watercraft where a direct connection shall be made to the engine. The total length of the strip shall be not less than 4 ft (1.2 m).

In a sailboat, the backstray and engine shall be electrically connected to the aft end of the strip. The strip shall be secured to the hull with one, or preferably two galvanically compatible throughbolts at each end. The bolts shall have a minimum cross-sectional area equivalent to a No. 4 AWG copper conductor. The strip shall be located so that it is submerged under all operating conditions. If the single strip is not located so as to be continuously submerged when the vessel is heeled either to port or starboard, then a strip shall be required on both port and starboard sides. Where more than one grounding strip is provided, all of the grounding strips shall be bonded together.

All terminations to the strip shall be made as short and direct as possible.

Additional through-hull connections shall be permitted to be located along the length of the strip for additional connections such as those on a two masted sailboat. Because of the possibility of stray current corrosion of the securing bolts, the number of through-hull bolts shall be kept to a minimum. To minimize the number of through-hull bolt connections, an equalization bus shall be permitted to be installed in accordance with Section 7-6.

The aft end of the grounding strip shall be connected directly to the engine negative ground terminal to provide a path inside the hull for any stray dc currents that are imposed on the through-hull bolts from the lightning grounding strip where those bolts contact bilge water.

7-6 Interconnection of Metallic Masses.

7-6.1 Equalization Bus.

On watercraft where several connections are made to the lightning grounding strip, an equalization bus shall be permitted to be installed inside the boat to minimize the number of through-hull bolts necessary. The equalization bus, if used, shall be installed inside the watercraft parallel to the underwater location of the lightning grounding strip. Permanently installed large metallic masses inside the watercraft shall be connected directly to the equalization bus. The equalization bus shall be connected to the underwater lightning grounding strip at both ends.

7-6.2 Seacocks and Through-Hull Fittings.

Seacocks and through-hull fittings shall not be connected to the main down conductor but shall be permitted to be connected to the underwater grounding strip, the lightning grounding plate, or the equalization bus.

NOTE: Seacocks are particularly susceptible to damage and leaking after a strike and should be inspected after all suspected strikes.

7-6.3 Metal Masses.

Metal masses such as engines, generators, metallic tanks, steering systems located inside the vessel, and other items such as metal life rails shall be connected to the lightning grounding plate, grounding strip or equalization bus as directly as possible.

7-6.4 Engine Grounding.

To minimize the flow of the lightning discharge currents through the engine bearings, it shall be permissible to ground the engine block directly to the lightning grounding plate or lightning grounding strip rather than to an intermediate point in the system.

7-6.5 Protection of Equipment.

Wherever possible, electronic equipment shall be enclosed in metal cabinets that are connected to the lightning grounding system with a minimum of a No. 8 AWG copper conductor. Surge suppression devices shall be installed on all wiring entering or leaving electronic equipment.

7-7 Nonmetallic Watercraft.

7-7.1 Sailboats.

Sailboats without inboard engines that are equipped with metallic masts and metallic rigging shall be considered to be adequately protected if the mast and the rigging chain plates are all connected to a lightning grounding plate or lightning grounding strip located directly below the mast.

7-7.1.1 Open Day-Sailors. Because the stainless steel rigging and preventors usually are not equivalent to No. 8 AWG copper conductor, adequate protection depends on the grounding of the rigging as well as the metal masts or the continuous metallic tracks on nonmetallic masts. These shall be connected at the lower ends to a lightning grounding plate or a lightning strip located directly below the mast. Metallic rudders at the aft end of the boat shall not be used as the lightning ground for the mast because of the need for a long, horizontal conductor to be run to the aft end of the boat. The tiller or other connections to metallic rudders the operator will contact shall be of nonconductive materials. Metallic keels or centerboards shall be directly connected to the lightning grounding plate or strip, or shall be permitted to serve as the lightning grounding means if they provide the l ft^2 (0.09 m^2) area required to be in contact with the water. If a centerboard is used as the lightning grounding means, a warning sign shall be provided that clearly states that the centerboard shall be in the down position in order to function as a lightning ground.

7-7.1.2 Cruising Sailboats. All shrouds, stays, sail tracks, and metallic masts shall be connected to the lightning grounding system, since it is assumed that occupants of the boat will be in proximity of forestays, backstays, and shrouds during the normal operation of the boat. Grounding of all metallic masses on the boat shall be in accordance with all applicable sections of this standard.

7-7.2* Power Boats.

Where practicable, lightning protection shall be provided through the use of a metallic radio antenna as described in Section 7-3.5, or a temporary air terminal as described in Section 7-3.6.

Appendix A Explanatory Material

This Appendix is not a part of the requirements of this NFPA document but is included for informational purposes only.

A-1-1.2

Electric generating facilities whose primary purpose is to generate electric power are excluded from this standard with regard to generation, transmission, and distribution of power. Most electrical utilities have standards covering the protection of their facilities and equipment. Installations not directly related to those areas and structures housing such installations can be protected against lightning by the provisions of this standard.

Lightning protection systems for structures used for production of storage of explosive materials require special consideration because of the sensitivity to arc or spark ignition of the structures' contents. Appendix K provides guidance for protection of structures housing explosive materials. Other standards and handbooks that provide guidance for military applications are found in Appendix M.

A-2-2 Approved.

The National Fire Protection Association does not approve, inspect, or certify any installations, procedures, equipment, or materials; nor does it approve or evaluate testing laboratories. In determining the acceptability of installations, procedures, equipment, or materials, the authority having jurisdiction may base acceptance on compliance with NFPA or other appropriate standards. In the absence of such standards, said authority may require evidence of proper installation, procedure, or use. The authority having jurisdiction may also refer to the listings or labeling practices of an organization concerned with product evaluations that is in a position to determine compliance with appropriate standards for the current production of listed items.

A-2-2 Authority Having Jurisdiction.

The phrase “authority having jurisdiction” is used in NFPA documents in a broad manner, since jurisdictions and approval agencies vary, as do their responsibilities. Where public safety is primary, the authority having jurisdiction may be a federal, state, local, or other regional department or individual such as a fire chief; fire marshal; chief of a fire prevention bureau, labor department, or health department; building official; electrical inspector; or others having statutory authority. For insurance purposes, an insurance inspection department, rating bureau, or other insurance company representative may be the authority having jurisdiction. In many circumstances, the property owner or his or her designated agent assumes the role of the authority having jurisdiction; at government installations, the commanding officer or departmental official may be the authority having jurisdiction.

A-2-2 Listed.

The means for identifying listed equipment may vary for each organization concerned with product evaluation, some of which do not recognize equipment as listed unless it is also labeled. The authority having jurisdiction should utilize the system employed by the listing organization to identify a listed product.

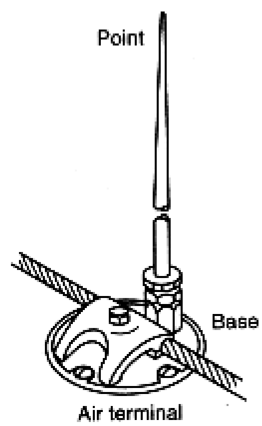


Figure A-2-2(a).

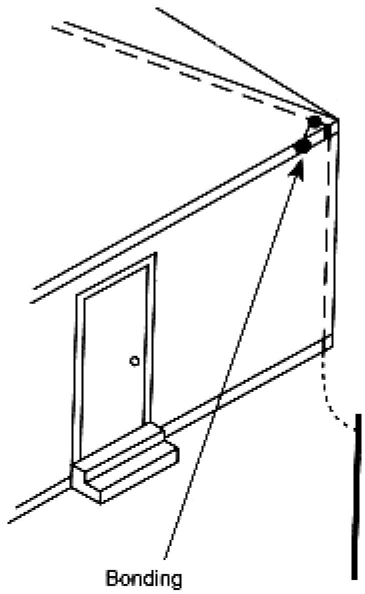


Figure A-2-2(b).

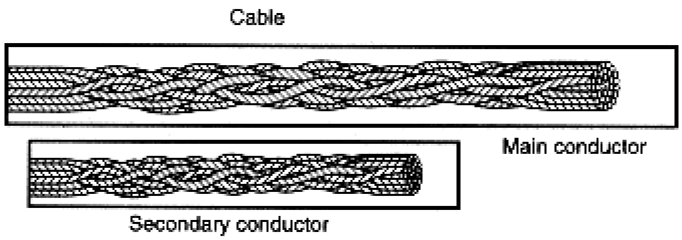


Figure A-2-2(c).

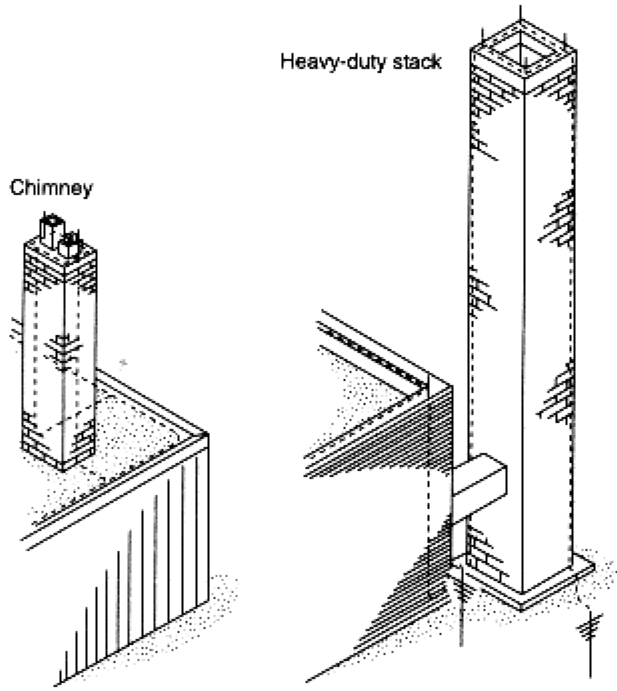


Figure A-2-2(d).

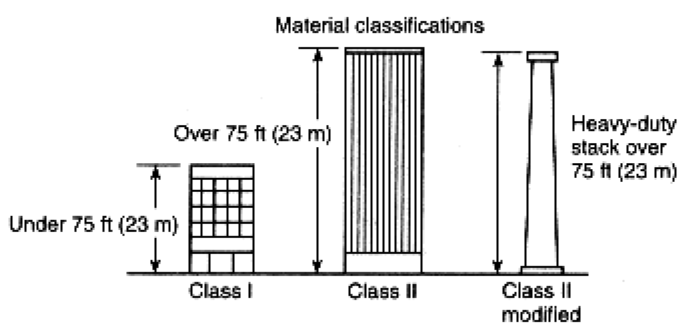


Figure A-2-2(e).

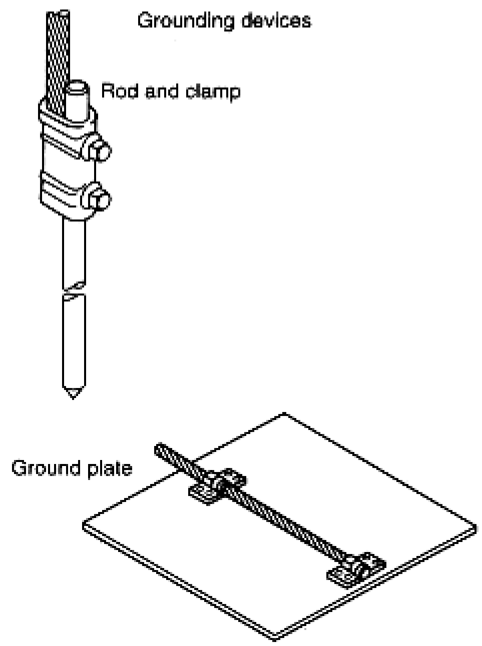


Figure A-2-2(f).

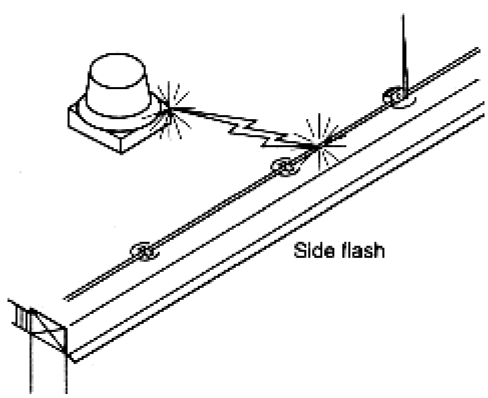


Figure A-2-2(g).

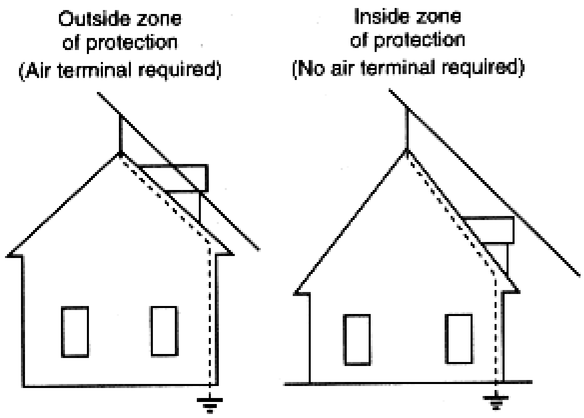


Figure A-3-11.2.

A-5-9

A ground grid located within 50 ft (15 m) of the foundation of a stack and constructed of wires meeting the requirements of this standard for main conductors is an acceptable ground terminal and, if the stack is located within 50 ft (15 m) of the grid in all directions, can also serve as the bottom loop conductor required by 5-4.1.

A-6-1.1

Flammable vapors can emanate from a flammable liquid [flash point below 100°F (37.8°C)] or a combustible liquid [flash point at or above 100°F (37.8°C)] when the temperature of the liquid is at or above its flash point. This chapter applies to these liquids when stored at atmospheric pressure and ambient temperature. Providing that the temperature of the liquid remains below the flash point, combustible liquids stored under these conditions will not normally release significant vapors since their flash point is defined to be at or above 100°F (37.8°C).

Metallic tanks, vessels, and process equipment that contain flammable or combustible liquids or flammable gases under pressure normally do not require lightning protection, since this equipment is well shielded from lightning strikes. Equipment of this type is normally well grounded and is thick enough not to be punctured by a direct strike.

This chapter applies to flammable or combustible liquids such as gasoline, diesel, jet fuel, fuel oil, or crude oil stored at atmospheric pressure. It does not apply to liquids or gases stored under pressure, such as liquefied natural gases or liquefied petroleum gases.

A-7-3.6

A solid stainless steel whip antenna or equivalent is permitted to be used because of its higher melting temperature, however it does not provide as low a resistance as a No. 4 AWG copper conductor.

A-7-4.2

Sideflash distances can be calculated using the formulas provided in Section 3-24. Sideflashes are more likely to occur if the routing of the lightning conductor is horizontal for some distance and if the metallic object provides a more direct path to ground.

A-7-7.2

At the approach of a thunderstorm, personnel should head for shore and quickly seek a land-based protected structure. There are many methods available by which lightning can be detected. These range from listening for static on AM radios, to single station detection devices, to sophisticated lightning location systems.

Appendix B Inspection and Maintenance of Lightning Protection Systems

This Appendix is not a part of the requirements of this NFPA document but is included for informational purposes only.

B-1 Inspection of Lightning Protection Systems.

B-1.1 Frequency of Inspections.

It is understood that all new lightning protection systems must be inspected following completion of their installation. However, it is also very important to make periodic inspections of existing systems. The interval between inspection should be determined by such factors as:

(a) classification of structure or area protected;

(b) level of protection afforded by the system;

(c) immediate environment (corrosive atmospheres);

(d) materials from which components are made;

(e) the type of surface to which the lightning protection components are attached.

B-1.1.1 In addition to the above, a lightning protection system should be inspected whenever any alterations or repairs are made to a protected structure, as well as following any known lightning discharge to the system.

B-1.1.2 It is recommended that lightning protection systems be visually inspected at least annually. In some areas where severe climatic changes occur it may be advisable to visually inspect systems semiannually or following extreme changes in ambient temperatures. Complete, in-depth inspections of all systems should be completed every 3 to 5 years. It is recommended that critical systems be so inspected every 1 to 3 years depending on occupancy or the environment in which the protected structure is located.

B-1.1.3 In most geographical areas, and especially in areas that experience extreme seasonal changes in temperature and rainfall, it is advisable to stagger inspections so that earth resistance measurements, for example, are made in the hot, dry months as well as the cool, wet months. Such staggering of inspections and testing is important in assessing the effectiveness of the lightning protection system during the various seasons throughout the year.

B-1.2 Visual Inspection.

Visual inspections are made to ascertain the following:

(a) The system is in good repair.

(b) There are no loose connections that might result in high resistance joints.

(c) No part of the system has been weakened by corrosion or vibration.

(d) All down conductors and ground terminals are intact (non-severed).

(e) All conductors and system components are securely fastened to their mounting surfaces and are protected against accidental mechanical displacement as required.

(f) There have not been additions or alterations to the protected structure that would require additional protection.

(g) There has been no visual indication of damage to surge suppression (over voltage) devices.

(h) The system complies in all respects with the current edition of this standard.

B-1.3 Complete Testing and Inspection.

Such testing and inspection includes the visual inspections described above in addition to the following:

(a) Perform tests to verify continuity of those parts of the system that were concealed (built-in) during the initial installation and that are not now available for visual inspection.

(b) Conduct ground resistance tests of the ground termination system and its individual ground electrodes if adequate disconnecting means have been provided. These test results should be compared with previous, or original, results or current accepted values, or both, for the soil conditions involved. If it is found that the test values differ substantially from previous values obtained under the same test procedures, additional investigations should be made to determine the reason for the difference.

(c) Perform continuity tests to determine if suitable equipotential bonding has been established for any new services or constructions that have been added to the interior of the structure since the last inspection.

B-1.4 Inspection Guides and Records.

Inspection guides or forms should be prepared and made available to the authority responsible for conducting inspections of lightning protection systems. These guides should contain sufficient information to guide the inspector through the inspection process so that he or she may document all areas of importance relating to the methods of installation, the type and condition of system components, test methods, and the proper recording of the test data obtained.

B-1.5 Records and Test Data.

The inspector or inspection authority should compile and maintain records pertaining to the following:

(a) The general condition of air terminals, conductors, and other components.

(b) The general condition of corrosion protection measures.

(c) The security of attachment of conductors and components.

(d) Resistance measurements of various parts of the ground terminal system.

(e) Any variations from the requirements contained in this standard.

B-2 Maintenance of Lightning Protection Systems.

B-2.1 General.

Maintenance of a lightning protection system is extremely important even though the lightning-protection design engineer has taken special precautions to provide corrosion protection, and has sized the components according to their particular exposure to lightning damage. Many system components tend to lose their effectiveness over the years because of corrosion factors, weather-related damage, and stroke damage. The physical, as well as the electrical, characteristics of the lightning protection system must be maintained in order to maintain compliance with design requirements.

B-2.2 Maintenance Procedures.

B-2.2.1 Periodic maintenance programs should be established for all lightning protection systems. The frequency of maintenance procedures is dependent on the following:

(a) weather related degradation;

(b) frequency of stroke damage;

(c) protection level required;

(d) exposure to stroke damage.

B-2.2.2 Lightning protection system maintenance procedures should be established for each system and should become a part of the overall maintenance program for the structure that it protects.

A maintenance program should contain a list of more or less routine items that can serve as a checklist so that a definite maintenance procedure can be followed regularly. It is the repeatability of the procedures that enhance the effectiveness of a good maintenance program.

A good maintenance program should contain provisions for the following:

(a) Inspection of all conductors and system components.

(b) Tightening of all clamps and splicers.

(c) Measurement of lightning protection system resistance.

(d) Measurement of resistance of ground terminals.

(e) Inspection or testing, or both, of surge suppression devices to determine their effectiveness compared with similar new devices.

(f) Refastening and tightening of components and conductors as required.

(g) Inspection and testing as required to determine if the effectiveness of the lightning protection system has been altered due to additions to, or changes in, the structure.

B-2.3 Maintenance Records.

Complete records should be kept of all maintenance procedures and routines and should include corrective actions that have been or will be taken. Such records provide a means of evaluating system components and their installation. They also serve as a basis for reviewing maintenance procedures as well as updating preventive maintenance programs.

Appendix C Guide for Personal Safety from Lightning

This Appendix is not a part of the requirements of this NFPA document but is included for informational purposes only.

C-1

The purpose of this appendix is to furnish a guide for personal safety from lightning. Personnel may be at risk prior to any visual or audible indication of a thunderstorm. Any time that conditions exist that might lead to lightning activity, personnel safety should be considered. Lightning warning systems are available to provide early warning of lightning activity.

C-2 Personal Conduct.

C-2.1

Do not go out-of-doors or remain out, unless it is necessary. Seek shelter as follows:

(a) dwellings or other buildings that are protected against lightning;

(b) underground shelters such as subways, tunnels, and caves;

(c) large metal-frame buildings;

(d) large unprotected buildings;

(e) enclosed automobiles, buses, and other vehicles with metal tops and bodies;

(f) enclosed metal trains and street cars;

(g) enclosed metal boats or ships;

(h) boats that are protected against lightning;

(i) city streets that may be shielded by nearby buildings.

C-2.2

If possible, avoid the following places, which offer little or no protection from lightning:

(a) small, unprotected buildings, barns, sheds, etc.;

(b) tents and temporary shelters;

(c) automobiles (nonmetal top or open);

(d) trailers (nonmetal or open).

C-2.3

Certain locations are extremely hazardous during thunderstorms and should be avoided if at all possible. Approaching thunderstorms should be anticipated, and the following locations avoided when storms are in the immediate vicinity:

(a) hilltops and ridges;

(b) areas on top of buildings;

(c) open fields, athletic fields, golf courses;

(d) parking lots and tennis courts;

(e) swimming pools, lakes, and seashores;

(f) near wire fences, clotheslines, overhead wires, and railroad tracks;

(g) under isolated trees;

(h) near electrical appliances, telephones, plumbing fixtures, and metal or electrically conductive objects.

C-2.4

In the above locations, it is especially hazardous to be riding in or on any of the following during thunderstorms:

(a) open tractors or other farm machinery operated in open fields;

(b) golf carts, scooters, bicycles, or motorcycles;

(c) open boats (without masts) and Hovercraft;

(d) automobiles (nonmetal top or open).

C-2.5

It may not always be possible to choose a location that offers good protection from lightning. Follow these rules when there is a choice in selecting locations:

(a) Seek depressed areas—avoid mountaintops, hilltops, and other high places.

(b) Seek dense woods—avoid isolated trees.

(c) Seek buildings, tents, and shelters in low areas—avoid unprotected buildings and shelters in high areas.

(d) If you are hopelessly isolated in an exposed area, drop to your knees and bend forward, putting your hands on your knees.

C-3 Protection for Personnel in Watercraft.

C-3.1

Inasmuch as the basic purpose of protection against lightning is to ensure the safety of personnel, it is appropriate that the following precautions and suggestions be listed in addition to all applicable recommendations in the preceding sections.

C-3.2

One should remain inside a closed boat, as far as practical, during a lightning storm and should not dangle arms or legs in the water.

C-3.3

To the extent consistent with safe handling and navigation of the boat during a lightning storm, one should avoid making contact with any items connected to a lightning protection system and especially in such a way as to bridge between these items. For example, it is undesirable that an operator be in contact with reversing gear levers and spotlight control handle at the same time.

C-3.4

No one should be in the water during a lightning storm.

Appendix D Protection for Livestock in Fields

This Appendix is not a part of the requirements of this NFPA document but is included for informational purposes only.

D-1 General.

D-1.1

The nature of the exposure of livestock in fields is such that it is not possible to eliminate the hazard entirely. However, application of the recommendations contained in this Appendix should minimize the hazard.

D-1.2

The loss of livestock due to lightning during thunderstorms is caused in large measure by herds congregating under isolated trees in open pastures or drifting against ungrounded wire fences and receiving a sufficient discharge to kill them.

D-1.3

In pastures where shelter is available from wooded areas of considerable size, isolated trees should be removed unless protection is provided.

D-1.4

Fences built with metal posts set in the earth are as safe from lightning as it is practical to make them, especially if the electrical continuity is broken. Breaking the electrical continuity is very useful in that it reduces the possibility of a lightning stroke affecting the entire length of a fence, as it can if the stroke is direct and the fence continuous, even though grounded. The fences that give rise to the most trouble are those constructed with posts of poorly conducting material, such as wood.

D-2 Grounding of Wire Fences.

D-2.1

Where it is desirable or necessary to mitigate the danger from wire fences constructed with posts of nonconducting material, D-2.2 and D-2.3 should be applied.

D-2.2 Iron Posts.

Ground connections may be made by inserting at intervals galvanized-iron posts, such as are ordinarily used for farm fencing, and attaching in electrical contact all of the wires of the fence, or by driving a length of not less than $^{1}/_{2}$ in. (12.7 mm) in diameter galvanized-iron pipe beside the fence and attaching the wires by ties of galvanized-iron wire. If the ground is normally dry, the intervals between metal posts should not exceed about 150 ft (46 m). If the ground is normally damp they may be placed up to about 300 ft (92 m) apart.

D-2.3 Depth of Grounds.

Pipes should be extended into the ground at least 2 ft (0.6 m).

D-3 Breaking Continuity of Fence.

D-3.1

In addition to grounding the fence, its electrical continuity should be broken by inserting insulating material in breaks in the wires at intervals of about 500 ft (150 m). These insertions may be in the form of fence panels of wood or lengths of insulating material to the ends of which the wires can be attached. Such lengths of insulating material may consist of strips of wood about 2 in. × 2 in. × 24 in. (50 mm × 50 mm × 600 mm), or their equivalent as far as insulating properties and mechanical strength are concerned.

D-3.2

In areas where herds may congregate along fences, the continuity should be broken at more frequent intervals than described in D-3.1.

Appendix E Protection for Picnic Grounds, Playgrounds, Ball Parks, and Other Open Places

This Appendix is not a part of the requirements of this NFPA document but is included for informational purposes only.

E-1 Picnic Grounds and Playgrounds.

Protection from lightning may be provided by the methods indicated in E-1.1 or E-1.2.

E-1.1 Shelters with Lightning Protection Systems.

Provide shelters with closed or open sides that are equipped with lightning protection systems. Down conductors should be shielded with nonconductive material resistant to impact and climate conditions to at least an 8-ft (2.4-m) height. Shelters with earthen floors should have: (1) ground terminals interconnected by an encircling, buried, bare copper conductor, or (2) ground terminals provided with buried radial conductors run out at least 10 ft (3 m) from the ground terminal away from the shelter.

E-1.2 Masts and Overhead Ground Wires.

Erect masts (poles) on opposite sides of the grounds and near the edges. Overhead wires should be strung between the masts at least 20 ft (6.1 m) above the ground level. Down conductors should be connected to the overhead wires with ground terminals. Down conductors should be shielded with material resistant to impact and climate conditions to at least an 8-ft (2.4-m) height. The wires should be not less than No. 4 AWG copper or equivalent. If steel masts are used, down leads are not necessary but the foot of the mast should be grounded. If the area to be protected is extensive, it may be necessary to erect several masts around the perimeter so that the area is covered by a network of wires to form a zone of protection. [*See Figures 6-3.3.1(a) and (b) in Chapter 6 for illustration.*]

E-2 Ball Parks and Racetracks.

E-2.1 Roofed Grandstands.

Roofed grandstands are included within the scope of this standard.

E-2.2 Open Grandstands and Open Spectator Areas.

Open grandstands and open spectator areas should be provided with masts and overhead ground wires as described in E-1.2.

E-3 Beaches.

Beaches should be provided with shelters as described in E-1.1.

E-4 Piers.

E-4.1 Covered Piers.

Covered piers are included within the scope of this standard.

E-4.2 Open Piers.

Open piers should be provided with masts and overhead ground wires as described in E-1.2.

Appendix F Protection for Trees

This Appendix is not a part of the requirements of this NFPA document but is included for informational purposes only.

F-1 General.

Trees with trunks within 10 ft (3 m) of a structure, or with branches that extend to a height above the structure should be equipped with a lightning protection system because of the danger of sideflash, fire, or superheating of the moisture in the tree, which could result in splintering of the tree. It might be desirable to equip other trees with a lightning protection system because of particular value to the owner. (*See Figure F-1.*)

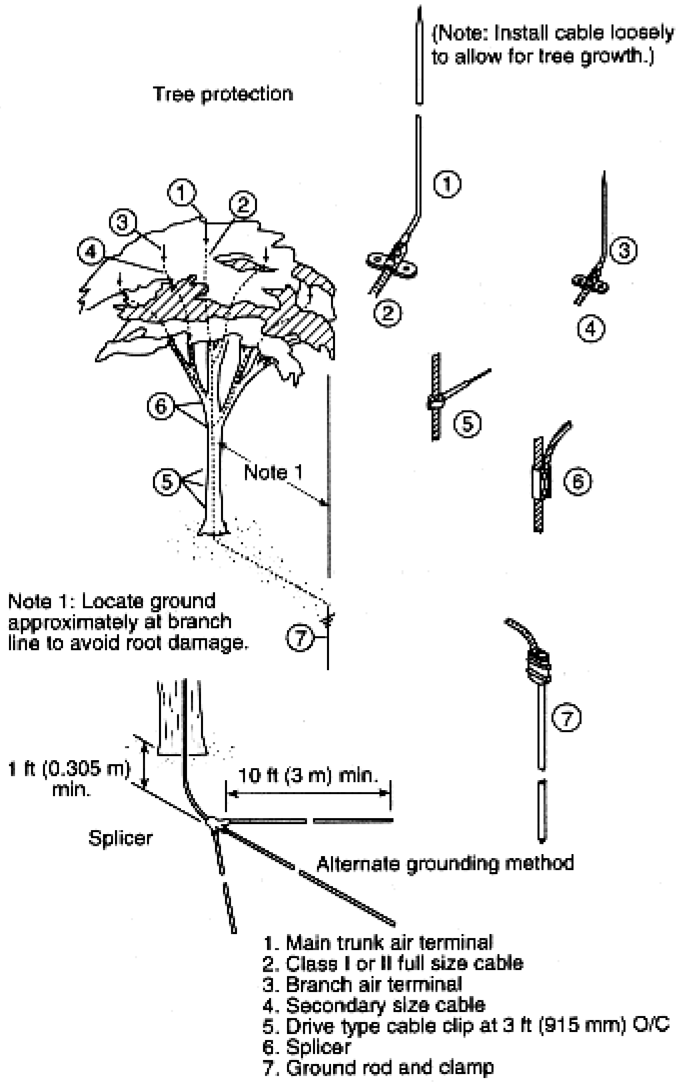


Figure F-1 Protection for trees.

F-2 Methods and Materials.

F-2.1 Conductors.

Conductors should conform to the requirements of Chapter 3.

F-2.2 Coursing of Conductors.

A single conductor should be run from the highest part of the tree along the trunk to a ground connection. If the tree is forked, branch conductors should be extended to the highest parts of the principal limbs. If the tree trunk is 3 ft (0.9 m) in diameter or larger, two down conductors should be run on opposite sides of the trunk and interconnected.

F-2.3 Air Terminals.

The conductors should be extended to the highest part of the tree terminating with an air terminal.

F-2.4 Attachment of Conductors.

Conductors should be securely attached to the tree in such a way as to allow for swaying in the wind and growth without danger of breakage.

F-2.5 Ground Terminals.

Ground terminals for conductors should:

(a) Be made from each conductor, descend the trunk of the tree, extend three or more radial conductors in trenches 1 ft (0.3 m) deep, and be spaced at equal intervals about the base to a distance of not less than 10 ft (3 m);

(b) Have the radial conductors extended to the branch line not less than 25 ft (7.6 m);

(c) Have the out ends connected to the radial conductors with a conductor that encircles the tree at a depth of not less than 1 ft (0.3 m); and

(d) Be bonded to an underground metallic water pipe where available within 25 ft (7.6 m) of the branch line.

Appendix G Protection for Parked Aircraft

This Appendix is not a part of the requirements of this NFPA document but is included for informational purposes only.

G-1 General Principles.

G-1.1

Aircraft includes airplanes, helicopters, and lighter-than-air craft. They can best be protected by being placed inside a properly lightning-protected hangar. Hangar facilities should be provided with grounding receptacles to permit interconnection of metal aircraft with the hangar lightning protection system. It is important that hangar floors, aprons, and aircraft parking areas be kept free of gasoline or other flammable liquids.

G-1.2

All metal airplanes parked outside hangars should be grounded. This grounding may be achieved by the use of adequately grounded metal tie-down cables or the equivalent. Aircraft having fabric or plastic covering materials can be protected by connecting its metal frame to ground. For additional protection of aircraft parked outside hangars, an overhead ground wire or mast-type lightning protection system may be provided. The height should be in accordance with the zones of protection described in Chapter 3.

G-1.3

The effects of lightning strikes to metal and composite aircraft are a matter of continuous study. The use of surge suppression circuitry on critical navigational, radio-communication, and radar equipment can help to minimize these effects. Suitable equipment and electrical wiring layout can also aid in reducing lightning-induced problems.

G-1.4

Commercial aircraft have grown considerably larger in recent years and in many cases are taller than surrounding airport terminal buildings. A review of available lightning-strike injury data indicates that nearly all of the reported personnel injuries were the result of lightning-induced static discharge.

G-1.5

The grounding methods used for aircraft undergoing fuel servicing and certain maintenance operations are not necessarily adequate to provide effective lightning protection for aircraft or personnel. The installation of additional grounding straps, preferably at the aircraft's extremities, during thunderstorm activity will provide alternative paths to ground for any current flow resulting from the rapid adjustment in the aircraft surface charge. Experience has shown that additional grounding straps offer little protection in the event of a direct strike to the aircraft. Fuel servicing operations and other maintenance operations involving the use of flammable liquids or the release of flammable vapors should be suspended during lightning storms. Refer to NFPA 407, *Standard for Aircraft Fuel Servicing*, and NFPA 410, *Standard on Aircraft Maintenance*.

G-1.6

Baggage handling, exterior maintenance, and servicing of parked aircraft should be suspended when a thunderstorm is in the vicinity of an airport. Lightning-warning equipment can be utilized to aid in determining when to suspend these operations. There are many detection methods capable of detecting and tracking approaching storms. One such method, atmospherics, is being used to establish lightning-detection networks that now cover approximately half of the United States. While atmospherics equipment can give positional information of distant lightning, it gives no warning of a cloud directly overhead becoming electrified. Devices that measure some property of the electric field can detect the development of a hazardous condition and provide a warning prior to the first discharge.

G-1.7

Cables connected to parked aircraft should not be handled when a thunderstorm is in the vicinity. The use of hand signals, without the use of headsets, is recommended for ground-to-cockpit communications during this period.

Appendix H Risk Assessment Guide

This Appendix is not a part of the requirements of this NFPA document but is included for informational purposes only.

H-1 General.

H-1.1

This lightning risk assessment guide is prepared to assist in the analysis of various criteria to determine the risk of loss due to lightning. As a guide, it is not possible to cover each special design element that may render a structure more or less susceptible to lightning damage. In special cases, personal and economic factors may be very important and should be considered in addition to the assessment obtained by use of this guide.

H-1.2

If the structure is in a high risk situation, a risk index (R) should be computed for a wide range of structures in the environment concerned. The structure's index is then compared to the index of these other structures so that a judgment of local risk weighting can be made.

H-2 Determining the Risk.

The assessment of risk index (R) is given in Table H-2. The risk index (R) is obtained by dividing the sum of the values given in Tables H-2(a) through H-2(e) by the lightning frequency index value obtained from Table H-2(f).

The risk index (R) is:

$$D = \frac{A + B + C + D + E}{F}$$

Table H-2 Assessment of Risk, R

R Value	Risk Value
0-2	Light
2-3	Light to Moderate
3-4	Moderate
4-7	Moderate to Severe
Over 7	Severe

The computed "R" values for the eastern United States should be multiplied by a factor varying from 1.5 in the northeast to 0.5 in the southeast. This factor is due to the differences in storm characteristics in these regions.

Table H-2(a) Index "A" – Type of Structure

Structure	Index Value
Single family residence less than 5,000 ft^2 (465 m^2)	1
Single family residence over 5,000 ft^2 (465 m^2)	2
Residential, office, or factory building less than 50 ft (15 m) in height:	
Covering less than 25,000 ft^2 (2,323 m^2) of ground area	3

Covering over 25,000 ft^2 (2,323 m^2) of ground area	5
Residential, office, or factory building from 50 ft to 75 ft (15 m to 23 m) high	4
Residential, office, or factory building from 75 ft to 150 ft (23 m to 46 m) high	5
Residential, office, or factory building from 150 ft (46 m) or higher	8
Municipal services buildings, fire, police, water, sewer, etc.	7
Hangars	7
Power-generating stations, central telephone exchanges	8
Water towers and cooling towers	8
Libraries, museums, historical structures	8
Farm buildings	9
Golf shelters and other recreational shelters	9
Places of public assembly such as schools, churches, theaters, stadiums	9
Slender structures such as smokestacks, church steeples and spires, control towers, lighthouses, etc.	10
Hospitals, nursing homes, housing for the elderly or handicapped	10
Buildings housing the manufacture, handling, or storage of hazardous materials	10

Table H-2(b) Index "B" – Type of Construction

Structural Framework	Roof Type	Index Value
Nonmetallic	Wood	5
(Other than wood)	Composition	3
	Metal — not continuous	4
	Metal — electrically continuous	1
Wood	Wood	5
	Composition	3
	Metal — not continuous	4
	Metal — electrically continuous	2
Reinforced Concrete	Wood	5

	Composition	3
	Metal — not continuous	4
	Metal — electrically continuous	1
Structural Steel	Wood	4
	Composition	3
	Metal — not continuous	3
	Metal — electrically continuous	1

NOTE: Composition roofs include asphalt, tar, tile, slate, etc.

Table H-2(c) Index "C" – Relative Location

Location	Index Value
Structures in areas of higher structures:	
Small structures — covering ground area of less than 10,000 ft^2 (929 m^2)	1
Large structures — covering ground area of more than 10,000 ft^2 (929 m^2)	2
Structures in areas of lower structures:	
Small structures — covering ground area of less than 10,000 ft^2 (929 m^2)	4
Large structures — covering ground area of more than 10,000 ft^2 (929 m^2)	5
Structures extending up to 50 ft (15.2 m) above adjacent structures or terrain	7
Structures extending more than 50 ft (15.2 m) above adjacent structures or terrain	10

Table H-2(d) Index "D" – Topography

Location	Index Value
On flat land	1
On hillside	2
On hilltop	4
On mountaintop	5

Table H-2(e) Index “E” – Occupancy and Contents

	Index Value
Noncombustible materials — unoccupied	1
Residential furnishings	2
Ordinary furnishings or equipment	2
Cattle and livestock	3
Small assembly of people — less than 50	4
Combustible materials	5
Large assembly of people — 50 or more	6
High value materials or equipment	7
Essential services — police, fire, etc.	8
Immobile or bedfast persons	8
Flammable liquids or gases — gasoline, hydrogen, etc.	8
Critical operating equipment	9
Historic contents	10
Explosives and explosive ingredients	10

Table H-2(f) Index “F” – Lightning Frequency Isoceraunic Level [See Figure H-2(f)(a) or H-2(f)(b)]

	Index Value
0-5	9
6-10	8
11-20	7
21-30	6
31-40	5
41-50	4
51-60	3
61-70	2
Over 70	1

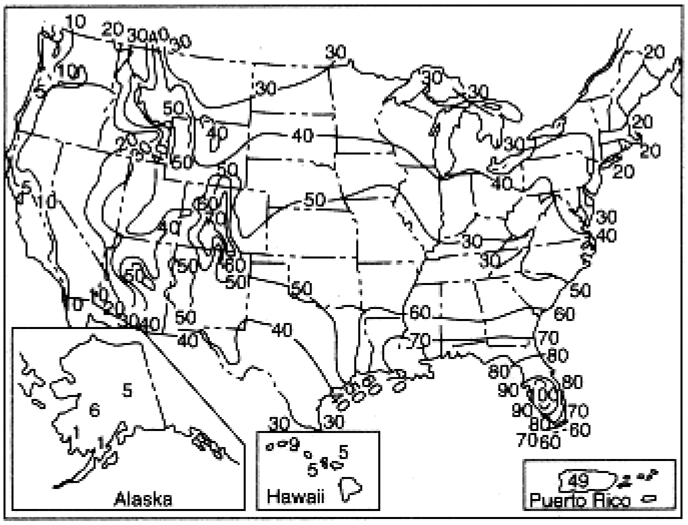


Figure H-2(f)(a) Statistics for continental United States showing mean annual number of days with thunderstorms. The highest frequency is encountered in south-central Florida. Since 1894, the recording of thunderstorms has been defined as the local calendar day during which thunder was heard. A day with thunderstorms is so recorded regardless of the number occurring on that day. The occurrence of lightning without thunder is not recorded as a thunderstorm. Statistics vary widely with local and climatic conditions. (Data supplied by Environmental Science Service Administration, U.S. Department of Commerce.)

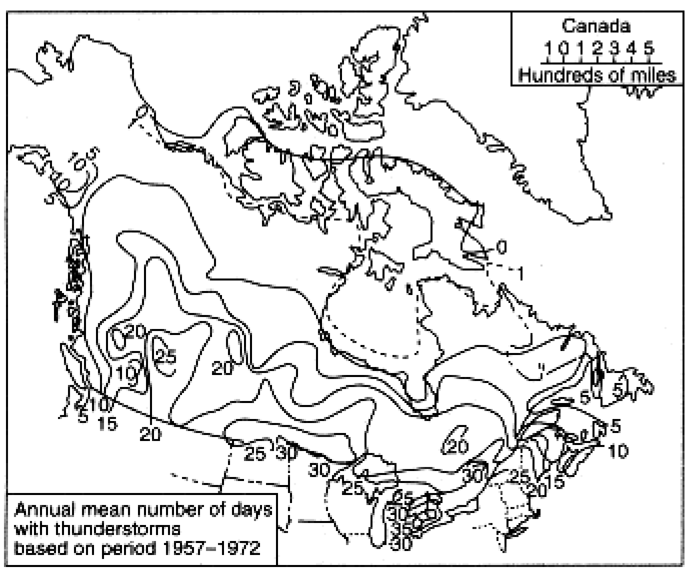


Figure H-2(f)(b) Canadian statistics showing annual average number of days with thunderstorms. Data based on the period 1957-1972. (Meteorological Division, Department of Transportation, Canada.)

Appendix I Ground Measurement Techniques

This Appendix is not a part of the requirements of this NFPA document but is included for informational purposes only.

In order to determine the ground resistance of a lightning protection system, it is necessary to remove it from any other ground connection. This may prove a virtually impossible task necessitating certain assumptions. In reality, ground-resistance measuring equipment works at low frequencies relative to the lightning discharge. The resistance it computes is therefore often affected by the resistance of power-system ground electrodes or a similar ground medium that may be several thousand feet from the structure being protected. The ground resistance to be used to calculate lightning conductor potentials when a high-frequency lightning discharge strikes a building must be the grounds in the immediate area of the building, not the remote ones that ground measuring equipment probably monitor.

If the building is small, and the lightning protection system can be disconnected totally from any other grounding network, its resistance can be measured by the three-point technique described below. If the building is large or cannot be disconnected totally from any other grounding network, then the ground resistance of individual isolated lightning-protection ground rods should be measured by the three-point technique described below and this resistance multiplied by a factor depending on the number of ground rods.

The principle of ground resistance measurement is shown in Figure I. L is the lightning ground rod or ground rod system, P is a test probe, and A an auxiliary current probe. M is the standard ac measuring equipment for three-point technique ground resistance measurements. Convenient distances for LP and LA are 75 ft (22 m) and 120 ft (36 m), respectively. In general, P should be at 62 percent of the distance from L to A. If 120 ft (36 m) is not convenient, it could be increased significantly [or reduced to no less than 50 ft (15.2 m)] provided LP is increased proportionately.

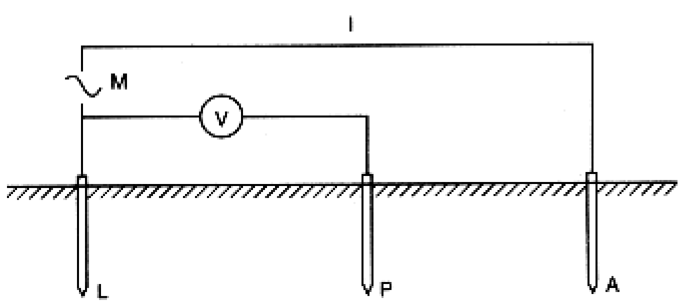


Figure I Measurement of ground resistance.

A current I is passed through the electrode or electrodes to be tested, L, and through an auxiliary probe A. The distance LA is long compared to the electrode length. The voltage V between L and P is measured by the test equipment, which also monitors I and calculates the ground resistance R as V/I. Alternating current is used to avoid errors due to electrolytic factors in the soil and to remove effects due to stray currents.

Three-point ground resistance measuring equipment using these principles is relatively inexpensive and allows direct reading of R.

Variations in soil resistivity due to temperature and moisture fluctuations can affect the measured ground resistance. A good designer will measure ground resistance under average or high resistivity conditions in order to design a lightning protection system to function adequately.

If the building ground is complex in nature, the resistance of single ground rods may be measured and certain assumptions made. The average single ground rod resistance, R_m, must be multiplied by a factor depending on the number of lightning-protection ground rods, n, spaced at least 35 ft (10.7 m) apart.

The total system ground resistance, R, can be calculated from the formula:

$$R = 1.1 \left(\frac{R_m}{n} \right)$$

Appendix J Explanation of Bonding Principles

This Appendix is not a part of the requirements of this NFPA document but is included for informational purposes only.

Lightning strikes may give rise to harmful potential differences in and on a building. The major concern in the protection of a building is the occurrence of potential differences between the conductors of the lightning protection system and other grounded metal bodies and wires belonging to the building. These potential differences are caused by resistive and inductive effects and can be of such a magnitude that dangerous sparking can occur. In order to reduce the possibility of sparking, it is necessary to equalize potentials by bonding grounded metal bodies to the lightning protection system.

Where installing (or modifying) lightning protection systems on existing structures, bonding of certain grounded metal bodies may present difficult installation problems due to the inaccessibility of building systems. Placement of conductors to avoid grounded metal bodies or increasing the number of down conductors to shorten the required bonding distances are options to overcome these problems.

Figure J illustrates the generation of these potential differences.

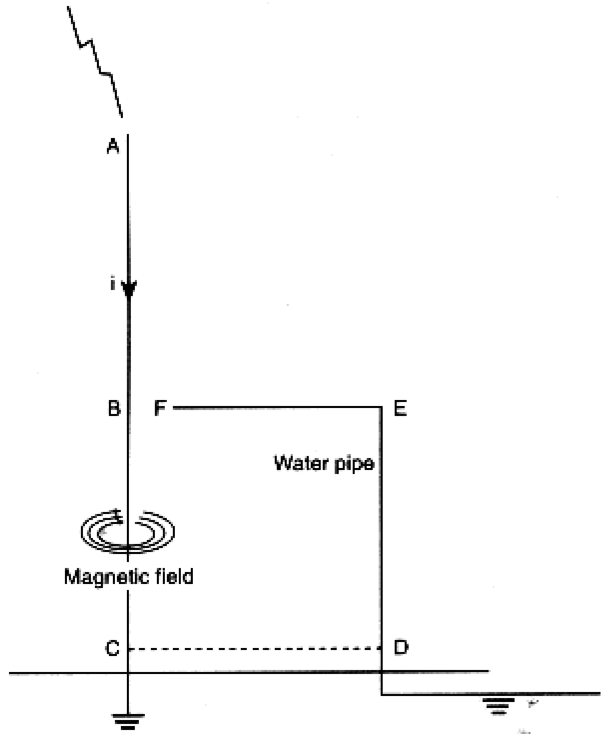


Figure J The magnetic field around a conductor.

(a) *Resistive Effect.* In the situation where conductor C is connected only to a ground terminal and the water pipe is independently grounded, a large potential may exist between B and F. Assuming a resistance of 20 ohms between C and ground and a lightning current of 100,000 amps, then Ohm's law (voltage = current X resistance) indicates that a potential of 2 million volts exists on conductor ABC. Because no current is initially passing through the water pipe, its potential is zero volts. The difference of potential of 2 million volts between B and F is sufficient for a sideflash of over 6 ft (2 m). In order to reduce this potential difference to zero, this standard requires equalization of potentials at ground level in accordance with 3-23.1. Such a bond is shown as CD in Figure J.

With bond CD in position the resistance between B and F is essentially zero, and hence during a lightning strike the potential at B due to the resistive effect is similar to that at F. Therefore the resistive effect can be neglected for bonding purposes.

(b) *Inductive Effect.* When a large current passes down the lightning conductor ABC a magnetic field is generated in circular motion around the conductor as shown in Figure J. The higher the lightning current, the higher the magnetic field. These magnetic field lines can be referred to as magnetic flux.

The loop BCDEF is intercepted by these lines of magnetic flux. The rate of change of the flux passing through this loop induces a voltage in the loop, creating a potential difference between B and F. This potential difference can be of the order of a few million volts, again causing a sideflash.

The bonding techniques described in this standard call for bonding the gaps, such as BF, over which high potentials exist in order to remove the spark and provide a safe path to ground for the current. The bonding-distance formulas are calculated from the laws of physics, making assumptions on the relevant lightning characteristics that influence the induced voltage. These assumptions for this standard are made for an extremely severe lightning current, thereby providing a bonding distance that is almost totally protective.

The voltage across the gap BF is related to the size of the loop BCDEF but dominantly to the height BC rather than CD; hence the height "h" term in the formulas of 3-24.2. Equalizing the potentials at frequent heights in accordance with Section 3-23 also reduces the size of the loop BCDEF, thereby keeping the gap voltage to a controllable value that can be removed by simple bonding.

One factor that is difficult to control is the problem related to power and communication lines entering the building. For all intents, such lines are at ground potential relative to the extremely high induced voltages. If the line DEF was such an electrical, telephone, power, or data line not bonded at ground, the voltage across the loop would be enhanced by the resistive effect described by Ohm's law as well as by the inductive effect, and hence BF could soon approach breakdown. This would lead to sparks causing fire as well as the obvious electrical, electronic, and human life problems. All such lines entering the building should have electrical bonding through surge protection as specified in Section 3-21, thereby reducing the resistive component and controlling dangerous sparking and damage. If just one wire, however, does not have such suppression devices the dangers described above still exist, even to the protected building and the electrical equipment. Table J shows sample calculations.

Table J Sample Calculations of Bonding Distances

		n = 1.0	n = 1.5	n = 2.25
h (ft)	**K_m**		**D**	
10	1.0	1 ft 8 in.	1 ft 1$^3/_8$ in.	9 in.
	0.5	10 in.	6$^3/_4$ in.	4$^1/_2$ in.
20	1.0	3 ft 4 in.	2 ft 2$^3/_4$ in.	1 ft 6 in.
	0.5	1 ft 8 in.	1 ft 1$^3/_8$ in.	9 in.
30	1.0	5 ft 0 in.	3 ft 4 in.	2 ft 2$^3/_4$ in.
	0.5	2 ft 6 in.	1 ft 8 in.	1 ft 1$^3/_8$ in.
40	1.0	6 ft 8 in.	4 ft 6 in.	3 ft
	0.5	3 ft 4 in.	2 ft 3 in.	1 ft 6 in.

In order to reduce the voltage across the gap BF so as to make bonding less necessary, it is possible to provide more down conductors. This standard requires down conductors every 100 ft (30 m) (*see 3-12.10*), but the number of down conductors, “n,” required in the bonding formula of 3-24.2 is restricted. It can be shown theoretically for structures less than 60 ft (18 m) in height that for a series of planar down conductors spaced 50 ft (15 m) apart “n” can be no bigger than 1.5, and for a similar three-dimensional situation “n” can be no bigger than 2.25. These values of “n” also apply to the upper 60 ft (18 m) of a tall structure. As the lightning current passes into the lower portion of a tall structure, however, the value of “n” must be calculated on the assumption that the current flow down the structure is much more symmetrical through the down conductors. This implies that for all but the upper 60 ft (18 m) of a structure the bonding distance can be calculated from a formula involving a larger value of “n,” as shown in 3-24.2.

Sideflashing can easily occur to grounded objects within the building. The intensity of the electric field in air is greater than that in concrete by approximately a factor of two, allowing for a reduction of the sideflash distance through a wall cavity.

If an individual touches a correctly bonded connection within the building, he or she should suffer no harm. This scenario is similar to that of a bird sitting on a high-voltage wire unaware that the bird’s potential is changing from over a thousand volts positive to over a thousand volts negative several times a second.

Appendix K Protection of Structures Housing Explosive Materials

This Appendix is not a part of the requirements of this NFPA document but is included for informational purposes only.

K-1 General.

This appendix provides the minimum technical requirements for lightning protection of structures housing explosive materials.

K-1.1

Due to the possibility of danger to the surrounding area, an increased level of protection efficiency as defined herein is necessary for such structures. The decision of when to protect these structures should be left to the authority having jurisdiction.

K-1.2

The protection of the contents contained in structures housing explosives must take into account the packages used to contain these materials as well as bonding or grounding requirements specified by the authority having jurisdiction.

K-2 Design Considerations.

Lightning protection systems designed to protect structures housing explosives and energetic materials should be based on a striking distance of 100 ft (33 m) as discussed in 6-3.3.

NOTE: When the effects of electromagnetic coupling are of concern, a mast of overhead wire (catenary) systems might be preferred over integral systems unless a Faraday cage or shield is required. The removal (isolation) of the down conductors will reduce the magnetic field strength in the structure and reduce the probability of a sideflash from a down conductor.

K-3 Types of Systems.

K-3.1 Mast-type Systems.

Mast-type systems should be designed as specified in 6-3.3.2.

K-3.2 Overhead Wire (Catenary) Systems.

Catenary systems should be designed as specified in 6-3.3.2.

K-3.3 Integral Systems.

An integral lightning protection system is a system that utilizes air terminals mounted directly on the structure to be protected. These types of air termination systems are as described in Chapter 3. Air terminal spacing should be modified as necessary to provide a zone of protection defined by a 100-ft (33-m) striking distance.

When an integral lightning protection system is used to protect the structures covered by this chapter, it is critical that the bonding requirements of Chapter 3 be met. It is also critical that a rigorous maintenance schedule be maintained for this type of system.

K-3.4 Faraday Cage.

The optimum scheme for protecting extremely sensitive operations from all forms of electromagnetic radiation is to enclose the operation(s) or facility inside a Faraday cage. A true Faraday cage is difficult to construct and economically justified only for critical facilities or where extremely sensitive operations warrant this level of protection.

Effective lightning protection is similarly provided by metallic structures such as those formed by the steel arch or the reinforcing steel in the walls and floors of earth-covered magazines if the steel reinforcement is bonded together and it meets the minimum ground system resistance requirements of K-4.

K-4 Grounding.

K-4.1 General.

A ground loop conductor is required for all lightning protection systems used to protect the subject structures. All down conductors, structural steel, ground rods, and other grounding systems should be connected to the ground loop conductor.

Exception: For structures with areas of 500 ft^2 (46.5 m^2) or less or those that can be protected by a single mast or air terminal, the ground loop conductors are not required.

K-4.2 Metal Portable Magazines.

Portable magazines that meet the requirements of a Faraday cage as described in K-3.4 should be grounded using a minimum of two ground terminations located at opposite corners within 1 ft (0.305 m) of ground level for large portable magazines. Additional ground rods should be added so the spacing should not exceed 60 ft (18.3 m) on average. Primary size conductors should be used to interconnect the portable magazine to the ground rods.

K-5 Bonding.

K-5.1 General.

It is critical that the bonding requirements of Chapter 3 be enforced for the protection of structures housing explosives or other energetic materials. The material used to bond items to the grounding loop conductor should meet the requirements of Section 3-2. Section 3-2 provides the requirements for the use of dissimilar metals.

K-5.2 Bonding Resistance.

The resistance of any object bonded to the lightning protection system should not exceed 1 ohm. For static dissipative systems such as conductive floors, workbenches, etc., bond resistance of 1 megohm is acceptable.

K-5.3 Painting.

Wires and conductors bonded to the lightning protection system should not be painted.

K-5.4 Magazines.

K-5.4.1 Earth-Covered Magazines. Metal ventilators, steel doors, door frames, and steel reinforcement should be bonded to the structure's grounding system. Incoming power, data, and communication cables should be bonded to the ground loop conductor or steel reinforcement as it enters the structure.

K-5.4.2 Metal Portable Magazines. Portable box-type magazines made of $^3/_{16}$-in. (4.8-mm) steel or equivalent where the walls, floor, and roof are welded together should require bonding of the doors across the hinges. Bonding of services, data lines, and communication lines should also be provided.

K-5.5 Fences.

Fences should have bonding across gates as well as other discontinuities and should be bonded to the lightning protection system ground loop conductor if they cross or come within the sideflash distance of the structure of a lightning protection system. Bonding across discontinuities in metallic fences should be provided as necessary to provide electrical continuity.

K-5.6 Railroad Tracks.

All railroad tracks that cross or come within the sideflash distance of a structure's lightning protection system should be bonded to the lightning protection system ground loop conductors. If the tracks are used to carry electrical signals, they should have insulated joints immediately external to bond the lightning protection system's ground loop conductor. If these tracks enter a facility, they should also be bonded to the frame of the structure (or equivalent).

K-6 Surge Suppression.

Surge suppression is required for all power, communication, or data conductors entering or exiting a structure housing explosives.

K-7 Maintenance and Inspection.

The effectiveness of a lightning protection system is best ensured by a quality control program designed to ensure that the system is not degraded by age, mechanical damage, or modifications to the structure. A maintenance and inspection plan should be developed for all protection systems used to protect structures housing explosives.

The initial installation should be inspected by the authority having jurisdiction (or their designated representative). It should be recertified after any work is done on the structure.

K-7.1 General.

To ensure that the protection system used to protect structures housing explosives is properly maintained, it is necessary that it be inspected visually twice a year and electrically approximately once a year. To ensure that the systems are tested during all four seasons over a 6-year period, 7-month and 14-month test cycles are suggested.

K-7.2 Visual (7-Month) Test.

The lightning protection system should be visually inspected every 7 months for evidence of corrosion or broken wires/connections. All necessary repairs should be made immediately. Any detected damage to the system should be entered in the test records as recommended in B-1.5.

K-7.3 Electrical (14-Month) Test.

The lightning protection system should be tested electrically every 14 months. The test should be conducted in accordance with the appropriate test equipment manufacturer's instructions by personnel familiar with lightning protection system testing.

K-7.4 Test Equipment.

Only those instruments designed specifically for earth ground systems testing are acceptable for use in ground resistance testing. The instrument must be capable of measuring 0 to 10 ohms ± 1 ohm. The instrument used to measure bonding resistance must be capable of measuring 0 to 1 ohm ± 0.1 ohm.

Appendix L Principles of Lightning Protection

This Appendix is not a part of the requirements of this NFPA document but is included for informational purposes only.

L-1 Fundamental Principles of Lightning Protection.

L-1.1

The fundamental principle in the protection of life and property against lightning is to provide a means by which a lightning discharge can enter or leave the earth without resulting damage or loss. A low impedance path should be offered, which the discharge current will follow in preference to all alternative high impedance paths offered by building materials such as wood, brick, tile, stone, or concrete. When lightning follows the higher impedance paths, damage may be caused by the heat and mechanical forces generated during the passage of the discharge. Most metals, being good electrical conductors, are virtually unaffected by either the heat or the mechanical forces if they are of sufficient size to carry the current that can be expected. The metal path must be continuous from the ground terminal to the air terminal. Care should be exercised in the selection of metal conductors to assure the integrity of the lightning conductor for an extended period. A nonferrous metal such as copper or aluminum will provide, in most atmospheres, a lasting conductor free of the effects of rust or corrosion.

L-1.2

Parts of structures most likely to be struck by lightning are those that project above surrounding parts such as chimneys, ventilators, flagpoles, towers, water tanks, spires, steeples, deck railings, shafthouses, gables, skylights, dormers, ridges, and parapets. The edge of the roof is the part most likely to be struck on flat-roofed buildings.

L-2 Lightning Protection Systems.

L-2.1

Lightning protection systems consist of three basic parts that provide the low impedance metal path required: (a) a system of air terminals on the roof and other elevated locations, (b) a system of ground terminals, and (c) a conductor system connecting the air terminals to the ground terminals. Properly located and installed, these basic components assure that the lightning discharge will be conducted harmlessly between the air terminals and the ground terminals.

L-2.2

While intercepting, conducting, and dissipating the main discharge, the three basic protection system components do not assure safety from possible secondary effects of a lightning strike. Therefore, secondary conductors are provided to interconnect metal bodies to assure that such metal bodies are maintained at the same electrical potential so as to prevent sideflashes or spark-over. Surge suppression devices are also provided to protect power lines and associated equipment from both direct discharges and induced currents.

L-2.3

Metal parts of a structure may be used as part of the lightning protection system in some cases. For example, the structural metal framing, which has sufficient cross-sectional area to equal the conductivity of main lightning conductors, and which is electrically continuous, may be used in lieu of separate down conductors. In such cases, air terminals are bonded to the framework at the top, and ground terminals are provided at the bottom, as described elsewhere in this standard. Structures with $^{3}/_{16}$-in. (4.8-mm) thick, or thicker, metal shells or skins that are electrically continuous might not require a system of air terminals and down conductors.

L-3 Items to Consider when Planning Protection.

L-3.1

The best time to design a lightning protection system for a structure is during the planning phase, and the best time to install the system can be during construction. System components may be built-in so as to be protected from mechanical displacement and environmental effects. In addition, aesthetic advantages may be gained by such concealment. It is generally less expensive to meet lightning protection requirements during construction.

L-3.2

The structure should be examined, and installation of air terminals should be planned for all areas or parts likely to receive a lightning discharge. The object is to intercept the discharge immediately above the parts liable to be struck and to provide a direct path to earth, rather than to attempt to divert the discharge in a direction it would not be likely to take. The air terminals should be placed high enough above the structure to obviate danger of fire from the arc.

L-3.3

Conductors should be installed to offer the least impedance to the passage of stroke current between the air terminals and earth. The most direct path is best, and there should be no sharp bends or narrow loops. The impedance of the conductor system is practically inversely proportional to the number of widely separated paths. Accordingly, there should be at least two paths to ground and more, if practicable, from each air terminal. The number of paths is increased and the impedance decreased by connecting the conductors to form a cage enclosing the building.

L-3.4

Properly made ground connections are essential to the effective functioning of a lightning protection system, and every effort should be made to provide ample contact with the earth. This does not necessarily mean that the resistance of the ground connection should be low, but rather that the distribution of metal in the earth or upon its surface in extreme cases should be such as to permit the dissipation of a stroke of lightning without damage.

L-3.5

Low resistance is desirable, but not essential, as may be shown by the extreme case on the one hand of a building resting on moist clay soil, and on the other by a building resting on bare solid rock. In the first case, if the soil is of normal resistivity or from 4,000 ohm-centimeters to 50,000 ohm-centimeters, the resistance of a ground connection made by extending the conductor 10 ft (3 m) into the ground will be from about 15 ohms to 200 ohms, and two such ground connections on a small rectangular building have been found by experience to be sufficient. Under these favorable conditions, providing adequate means for collecting and dissipating the energy of a flash without serious chance of damage is a simple and comparatively inexpensive matter.

L-3.6

In the second case, it would be impossible to make a ground connection in the ordinary sense of the term because most kinds of rocks are insulating, or at least of high resistivity, and in order to obtain effective grounding other more elaborate means are necessary. The most effective means would be an extensive wire network laid on the surface of the rock surrounding the building to which the down conductors could be connected. The resistance to earth at some distant point of such an arrangement would be high but at the same time the potential distribution about the building would be substantially the same, as though it were resting on conducting soil, and the resulting protective effect also would be substantially the same.

L-3.7

In general, the extent of the grounding arrangements will depend on the character of the soil, ranging from simple extension of the conductor into the ground where the soil is deep and of high conductivity to an elaborate buried network where the soil is very dry or of very poor conductivity. Where a network is required, it should be buried if there is soil enough to permit it, as this adds to its effectiveness. Its extent will be determined largely by the judgment of the person planning the installation with due regard to the rule: the more extensive the underground metal available, the more effective the protection.

L-3.8

Where practicable, each ground connection should extend or have a branch that extends below and at least 2 ft (0.6 m) away from the foundation walls of the building; otherwise there is a chance of the wall being damaged.

L-3.9

When a lightning conductor system is placed on a building, within or about which there are metal objects of considerable size within a few feet of a conductor, there will be a tendency for sparks or sideflashes to jump between the metal object and the conductor. To prevent damage, interconnecting conductors should be provided at all places where sideflashes are likely to occur.

L-3.10

Lightning currents entering protected buildings on overhead or underground power lines, or telephone conductors, or television or radio antennas are not necessarily restricted to associated wiring systems and appliances. Therefore, such systems should be equipped with appropriate protective devices and bonded to assure a common potential.

L-3.11

Because a lightning protection system is expected to remain in working condition for long periods with minimum attention, the mechanical construction should be strong, and the materials used should offer resistance to corrosion and mechanical injury.

L-4 Inspection and Maintenance of Lightning Protection Systems.

It has been shown that in cases where damage has occurred to a protected structure, the fault was due to additions or repairs to the building or to deterioration or mechanical damage that was allowed to go undetected and unrepaired, or both. Therefore, it is recommended that an annual visual inspection be made and that the system be thoroughly inspected every 5 years.

L-5 Indirect Losses.

In addition to direct losses such as destruction of buildings by lightning, fire resulting from lightning, the killing of livestock, etc., indirect losses sometimes accompany the destruction or damage of buildings and their contents. An interruption to business or farming operations, especially at certain times of the year, may involve losses quite distinct from, and in addition to, the losses arising from the direct destruction of material property. There are cases where whole communities depend on the integrity of a single structure for their safety and comfort. For example, they may depend on a water-pumping plant, a telephone relay station, a police station, or a fire station. A stroke of lightning to the unprotected chimney of a pumping plant, for example, might have a serious consequence from a lack of sanitary drinking water, irrigating water, or water for fire protection.

Appendix M Referenced Publications

This Appendix is not a part of the requirements of this NFPA document but is included for informational purposes only.

M-1

The following documents or portions thereof are referenced within this standard for informational purposes only and thus should not be considered part of the requirements of this document. The edition indicated for each reference is the current edition as of the date of the NFPA issuance of this document.

M-1.1 NFPA Publications.

National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA

02269-9101.

NFPA 70, *National Electrical Code*, 1996 edition

NFPA 407, *Standard for Aircraft Fuel Servicing*, 1990 edition

NFPA 410, *Standard on Aircraft Maintenance*, 1994 edition.

M-1.2 Military Publications.

This publication makes reference to the following military standards and handbook. They are available from Naval Publications and Forms Center, Philadelphia, PA; Headquarters, Army Material Command Code DRXAM-ABS, Alexandria, VA or Air Force Publications Center, Baltimore, MD.

DoD 6055.9-STD, *Ammunition and Explosives Safety Standards*, Chapter 7, Dept. of Defense, Washington, DC, October 1992

NAVSEA OP-5, *Ammunition and Explosives Ashore*, Volume 1, Fourth Revision, Chapter 4, Naval Sea Systems Command, Washington, DC, May 1983

AMCR 385-100, *Safety Manual*, Chapter 8, Army Material Command, Washington, DC, 1985

AFR 127-100, *Explosives Safety Standards*, Dept. of Air Force, Washington, DC, May 1983

MIL-HDBK-419, *Grounding, Bonding and Surge Suppression*, Volumes I and II, Dept. of Defense, Washington, DC, January 1982.

Formal Interpretation

NFPA 780

Lightning Protection Code

1995 Edition

Reference : 3-12.13
F.I. 86-1

Question 1: Is it the intent of 3-12.13 that down conductors be bonded to the reinforcing steel at the top and bottom where conductors are sleeved with PVC and embedded in concrete?

Answer: Yes.

Question 2: Is it the intent of 3-12.13 to apply conductors installed in PVC conduit embedded in concrete?

Answer: Yes.

Question 3: Is it the intent of 3-12.13 that conductors embedded in steel reinforced concrete be bonded to the reinforcing steel where conductors enter and emerge from the concrete?

Answer: Yes.

Question 4: Is it the intent of 3-12.13 that conductors embedded in steel reinforced concrete be bonded to the reinforcing steel where conductors enter and emerge from the concrete even if entrance and exit is not at the top and bottom?

Answer: Yes.

Issue Edition: 1986 of NFPA 78
Reference:– 3-24.2
Date: March 1988

Lightning Protection Code

1995 Edition

Reference : Appendix Item I-2
FI 92-1 (NFPA 780)

Question: Is the multiplying factor "1.5" the correct factor to be used for locations in the northeastern United States?

Answer: Yes.

Issue Edition: 1992
Reference: Appendix Item I-2
Issue Date: September 22, 1993
Effective Date: October 12, 1993

Lightning Protection Code

1995 Edition

Reference : Appendix Item I-2
FI 92-2 (NFPA 780)

Question: Is the multiplying factor "0.5" the correct factor to be used for locations in the southeastern United States?

Answer: Yes.

Issue Edition: 1992
Reference: Appendix Item I-2
Issue Date: September 22, 1993
Effective Date: October 12, 1993

NFPA 801

1995 Edition

Standard for Facilities Handling Radioactive Materials

1995 Edition

This edition of NFPA 801, *Standard for Facilities Handling Radioactive Materials*, was prepared by the Technical Committee on Atomic Energy and acted on by the National Fire Protection Association, Inc., at its Fall Meeting held November 14-16, 1994, in Toronto, Ontario, Canada. It was issued by the Standards Council on January 13, 1995, with an effective date of February 7, 1995, and supersedes all previous editions.

The 1995 edition of this document has been approved by the American National Standards Institute.

Origin and Development of NFPA 801

The Committee on Atomic Energy was organized in 1953 for the purpose of providing the fire protection specialist with certain fundamental information about radioactive materials and their handling and to provide designers and operators of such laboratories with some guidance on practices necessary for fire safety. The first edition of NFPA 801, whose coverage was limited to laboratories handling radioactive materials, was adopted at the 1955 Annual Meeting.

In 1970 the format was revised, and it was updated to reflect current thinking and practices. It was also expanded to apply to all locations, exclusive of nuclear reactors, where radioactive materials are stored, handled, or used.

The 1975 edition was a reconfirmation of the 1970 edition with editorial changes.

The 1980 edition included a clarified statement regarding the presence of and levels of radiation; cautionary statements about the assumption of risks by the fire officer and the importance of training in the handling of radioactive materials by fire department personnel; a clarification concerning the variations of the intensity of a radiation field; and a restyling of the document to conform with the NFPA *Manual of Style*.

The 1985 edition revised and updated previous material for clarification in recognition of technology and terminology changes.

The 1991 edition was a total revision of the document and included a complete reorganization of the chapters. This was done to provide an update of the latest technology and to improve the document's user friendliness.

This latest 1995 edition includes a variety of updates necessary to convert the document from a recommended practice to a standard. One of the more noteworthy changes is a revised scope statement to recognize a threshold value with respect to the amount of radioactive materials that are stored, handled, or used.

Technical Committee on Atomic Energy

Walter W. Maybee, *Chair*
Los Alamos Nat'l Laboratories, NM

Wayne D. Holmes, *Secretary*
HSB Professional Loss Control Inc., PA

Mario A. Antonetti, Gage-Babcock & Assoc. Inc., NY

William G. Boyce, U.S. Dept. of Energy, DC

Harry M. Corson, Cerberus Pyrotronics, NJ
Rep. Nat'l Electrical Mfrs. Assn.

Donald A. Diehl, Alison Control Inc., NJ

Paul H. Dobson, Factory Mutual Research Corp., MA

Stewart M. Fastman, American Insurance Services Group Inc., NY

Paul Giaccaglia, American Nuclear Insurers, CT

Arie T. P. Go, Bechtel Corp., CA

Leonard R. Hathaway, M&M Protection Consultants, IL

LeRoy J. Hill, McDermott Inc., VA

L. S. Homa, Underwriters Laboratories Inc., IL

Jacob B. Klevan, Rolf Jensen & Assoc. Inc., VA

Thomas J. Kramer, Schirmer Engineering Corp., IL

Robert S. Levine, Nat'l Inst. of Standards & Technology, MD

Patrick M. Madden, U.S. Nuclear Regulatory Commission, DC

Anthony J. Mascena, Stone & Webster Engr Corp., NJ

Brian J. Meacham, FireTech, Switzerland

David P. Notley, Science Applications Int'l Corp. (SAIC), VA

Robert J. O'Laughlin, Knoxville, TN

Chandrakant A. Oza, General Electric Co., CA

Mark Henry Salley, Tennessee Valley Authority, TN

Jack Siegel, Ebasco, NY

Clifford R. Sinopoli, Baltimore Gas & Electric, MD
Rep. Electric Light Power Group/Edison Electric Inst.

Wayne R. Sohlman, Nuclear Mutual Ltd, DE

Rupert M. H. Terrier, Virginia Electric & Power Co., VA

Lynn K. Underwood, Wausau Insurance Cos., WI
Rep. The Alliance of American Insurers

Steven F. Vieira, Grinnel Fire Protection Systems Co., RI
Rep. Nat'l Fire Sprinkler Assn.

Michael J. Vitacco, Westinghouse Savannah River Co., SC

Alternates

Daniel L. Arnold, Rolf Jensen & Assoc., GA
(Alt. to J. B. Klevan)

Ingemar B. Asp, Gage-Babcock & Assoc. Inc., NY
(Alt. to M. A. Antonetti)

James B. Biggins, M&M Protection Consultants, IL
(Alt. to L. R. Hathaway)

Warren D. Bonisch, Schirmer Engr Corp., VA
(Alt. to T. J. Kramer)

Dennis Eaves, American Nuclear Insurers, CT
(Alt. to P. Giaccaglia)

L. Paul Herman, HSB Professional Loss Control, Inc., IL

(Alt. to W. D. Holmes)

Neal W. Krantz, Simplex, MI
(Alt. to H. M. Corson)

Jimmy J. Pierce, Tennessee Valley Authority, TN
(Alt. to M. H. Salley)

Thomas A. Storey, Science Applications Int'l Corp. (SAIC), VA
(Alt. to D. P. Notley)

Robert W. Strong, General Electric Co., CA
(Alt. to C. A. Oza)

Brian D. Tomes, Wausau Insurance Cos., TX
(Alt. to L. K. Underwood)

Nonvoting

Donald J. Keigher, Los Alamos, NM
(Member Emeritus)

Casey C. Grant, NFPA Staff Liaison

This list represents the membership at the time the Committee was balloted on the text of this edition. Since that time, changes in the membership may have occurred.

NOTE: Membership on a Committee shall not in and of itself constitute an endorsement of the Association or any document developed by the Committee on which the member serves.

Committee Scope: This Committee shall have primary responsibility for documents on the safeguarding of life and property from fires in which radiation or other effects of nuclear energy might be a factor.

NFPA 801
Standard for
Facilities Handling Radioactive Materials

1995 Edition

NOTICE: An asterisk (*) following the number or letter designating a paragraph indicates explanatory material on that paragraph in Appendix A.
Information on referenced publications can be found in Chapter 6 and Appendix C.

Chapter 1 Introduction

1-1 Scope.

1-1.1*

This standard addresses fire protection requirements intended to reduce the risk of fires and explosions at facilities handling radioactive materials. These requirements are applicable to all locations where radioactive materials are stored, handled, or used in quantities and conditions requiring a U.S. Nuclear Regulatory Commission license to possess or use these materials or in equal quantities or conditions at other locations.

1-1.2

This standard shall not apply to research or power reactors that are covered by NFPA 802, *Recommended Fire Protection Practice for Nuclear Research and Production Reactors*, and NFPA 803, *Standard for Fire Protection for Light Water Nuclear Power Plants*.

1-2* Purpose.

This standard provides requirements for personnel responsible for the design or operation of facilities that involve the storage, handling, or use of radioactive materials.

1-3 Alternative Methods.

1-3.1

Nothing in this standard is intended to prevent or discourage the use of alternative methods, practices, or devices, provided that sufficient technical data are submitted to the authority having jurisdiction to demonstrate that the alternative method, material, practice, or device is equivalent to or superior to the requirements of this standard.

1-3.2

It is intended that a designer capable of applying more complete and rigorous analysis to special or unusual problems shall have latitude in the development of the applicable design. In such cases, the designer shall be responsible for demonstrating the validity of the approach. This standard does not do away with the need for competent engineering judgment and is not intended as a design handbook.

1-4 Retroactivity.

1-4.1

The provisions of this standard shall be considered necessary to provide a reasonable level of protection from loss of life and property from fire or explosion. They reflect situations and the state of the art at the time the standard was issued.

1-4.2

Unless otherwise noted, the provisions of this standard shall not be applied retroactively, except in those cases where it is determined by the authority having jurisdiction that the existing situation involves a distinct hazard to life or adjacent property.

1-5 Definitions.

Alpha Particle. A positively charged particle emitted by certain radioactive materials, identical to the nucleus of a helium atom. It is the least penetrating of the three common types of radiation (alpha, beta, gamma) emitted by radioactive material, as it is stopped by a sheet of paper. It is not dangerous to plants, animals, or people unless the alpha-emitting substance has entered the body.

Approved. Acceptable to the authority having jurisdiction.

NOTE: The National Fire Protection Association does not approve, inspect, or certify any installations, procedures, equipment, or materials; nor does it approve or evaluate testing laboratories. In determining the acceptability of installations, procedures, equipment, or materials, the authority having jurisdiction may base acceptance on compliance with NFPA or other appropriate standards. In the absence of such standards, said authority may require evidence of proper installation, procedure, or use. The authority having jurisdiction may also refer to the listings or labeling practices of an organization concerned with product evaluations that is in a position to determine compliance with appropriate standards for the current production of listed items.

Authority Having Jurisdiction. The organization, office, or individual responsible for approving equipment, an installation, or a procedure.

NOTE: The phrase "authority having jurisdiction" is used in NFPA documents in a broad manner, since jurisdictions and approval agencies vary, as do their responsibilities. Where public safety is primary, the authority having jurisdiction may be a federal, state, local, or other regional department or individual such as a fire chief; fire marshal; chief of a fire prevention bureau, labor department, or health department; building official; electrical inspector; or others having statutory authority. For insurance purposes, an insurance inspection department, rating bureau, or other insurance company representative may be the authority having jurisdiction. In many circumstances, the property owner or his or her designated agent assumes the role of the authority having jurisdiction; at government installations, the commanding officer or departmental official may be the authority having jurisdiction.

Beta Particle. An elementary particle emitted from a nucleus during radioactive decay, with a single electrical charge and a mass equal to 1/1,837 that of a proton. A negatively charged beta particle is identical to an electron, and a positively charged beta particle is called a positron. Beta radiation can cause skin burns, and beta-emitters are harmful if they enter the body. However, beta particles are easily stopped by a thin sheet of metal.

Canyon. An enclosure beside or above a series of hot cells for the purpose of servicing the hot cells.

Cave. A small hot cell intended for a specific purpose and limited equipment.

Combustible.* Any material that, in the form in which it is used and under the conditions anticipated, will ignite and burn. A material that does not meet the definition of noncombustible or limited-combustible.

Combustible Liquid. A liquid having a flash point at or above 100°F (37.8°C).

NOTE: See NFPA 30, *Flammable and Combustible Liquids Code*.

Criticality. The state of sustaining a chain reaction, as in a nuclear reactor.

Criticality Incident. An accidental, self-sustained nuclear fission chain reaction.

Decontamination. The removal of unwanted radioactive substances from personnel, rooms, building surfaces, equipment, etc., to render the affected area safe.

Fire Area. That portion of a building or facility that is separated from other areas by fire barriers.

Fire Barrier. A fire barrier is a continuous membrane, either vertical or horizontal, such as a wall or floor assembly, that is designed and constructed with a specified fire resistance rating to limit the spread of fire and that will also restrict the movement of smoke. Such barriers might have protected openings.

Fire Brigade. As used in this standard, refers to those facility personnel trained in plant fire-fighting operations.

Fire Door. A door assembly rated in accordance with NFPA 252, *Standard Methods of Fire Tests of Door Assemblies*, and installed in accordance with NFPA 80, *Standard for Fire Doors and Fire Windows*.

Fire Hazards Analysis. A comprehensive assessment of the potential for a fire at any location to ensure that the possibility of injury to people or damage to buildings, equipment, or the environment is within acceptable limits.

Fire Prevention. Measures directed toward avoiding the inception of fire.

Fire Protection. Methods of providing for fire control or fire extinguishment.

Fire Resistance Rating. The time, in minutes or hours, that materials or assemblies have withstood a fire exposure as established in accordance with the test procedures of NFPA 251, *Standard Methods of Fire Tests of Building Construction and Materials*.

Fire Risk Analysis. An analysis to quantify the fire risk by determining the probability of a fire and to evaluate the probability of resultant injury to people or damage to buildings or equipment.

Fire Zone. Subdivisions of fire areas in which fire detection or suppression systems provide alarm information indicating the location of fire at a central fire control center.

Flame Spread Rating. A relative measurement of the surface burning characteristics of building materials when tested in accordance with NFPA 255, *Standard Method of Test of Surface Burning Characteristics of Building Materials*.

Flammable Liquid. Any liquid having a flash point below 100°F (37.8°C) and having a vapor pressure not exceeding 40 psi (276 kPa) absolute pressure at 100°F (37.8°C).

Gamma Rays. High-energy, short-wavelength electromagnetic radiation. Gamma radiation frequently accompanies alpha and beta emissions and always accompanies fission. Gamma rays are very penetrating and are best stopped or shielded against by dense material, such as depleted uranium, lead, water, concrete, or iron.

Glove Box. A sealed enclosure in which items inside the box are handled exclusively using long rubber or neoprene gloves sealed to ports in the walls of the enclosure. The operator places hands and forearms into the gloves from the room side of the box in order to maintain physical separation from the glove box environment while retaining the ability to manipulate items inside the box with relative freedom while viewing the operation through a window.

Hot Cell. A heavily shielded enclosure in which radioactive material can be handled safely by persons working from outside the shield using remote tools and manipulators while viewing the work through special leaded glass or liquid-filled windows or through optical devices.

Isotope. Any of two or more forms of an element having the same atomic number and similar chemical properties but differing in mass number and radioactive behavior.

Labeled. Equipment or materials to which has been attached a label, symbol, or other identifying mark of an organization that is acceptable to the authority having jurisdiction and concerned with product evaluation that maintains periodic inspection of production of labeled equipment or materials and by whose labeling the manufacturer indicates compliance with appropriate standards or performance in a specified manner.

Limited-Combustible.* A building construction material that, in the form in which it is used, has a potential heat value not exceeding 3,500 Btu/lb (8,141 kJ/kg) and has either a structural base of noncombustible material with a surfacing not exceeding $^{1}/_{8}$ in. (3.2 mm) that has a flame spread rating not greater than 50, or other material having neither a flame spread rating greater than 25 nor evidence of continued progressive combustion, even on surfaces exposed by cutting through the material on any plane.

NOTE: See NFPA 220, *Standard on Types of Building Construction*.

Listed. Equipment or materials included in a list published by an organization acceptable to the authority having jurisdiction and concerned with product evaluation that maintains periodic inspection of production of listed equipment or materials and whose listing states either that the equipment or material meets appropriate standards or has been tested and found suitable for use in a specified manner.

NOTE: The means for identifying listed equipment may vary for each organization concerned with product evaluation, some of which do not recognize equipment as listed unless it is also labeled. The authority having jurisdiction should utilize the system employed by the listing organization to identify a listed product.

Noncombustible.* A material that, in the form in which it is used and under the conditions anticipated, will not ignite, burn, support combustion, or release flammable vapors, when subjected to fire or heat. Materials that are reported as passing ASTM E136, *Standard Test Method for Behavior of Materials in a Vertical Tube Furnace at 750°C*, shall be considered noncombustible materials.

Radiation. The emission and propagation of energy through matter or space by means of electromagnetic disturbances that display both wave-like and particle-like behavior. The term includes streams of fast-moving particles, such as alpha and beta particles, free neutrons, and cosmic radiation. Nuclear radiation is that emitted from atomic nuclei in various nuclear reactions including alpha, beta, and gamma radiation and neutrons.

Radiation Area. An area accessible to personnel in which there exists radiation, originating in whole or in part within radioactive material, at such levels that a major portion of the body could receive a dose in excess of 5 millirems during any single hour or a dose in excess of 100 millirems during any five consecutive days.

Radioactivity. The spontaneous decay or disintegration of an unstable atomic nucleus accompanied by the emission of radiation.

Shall. Indicates a mandatory requirement.

Should. Indicates a recommendation or that which is advised but not required.

Standard. A document that contains only mandatory provisions using the word “shall” to indicate requirements. Explanatory material may be included only in the form of fine-print notes, in footnotes, or in an appendix.

1-6 Units.

Metric units in this document are in accordance with the International System of Units, which is abbreviated officially as “SI” in all languages.

NOTE: For a full explanation, see ASTM E380, *Standard Practice for Use of the International System of Units*.

Chapter 2 Administrative Controls

2-1 General.

2-1.1*

The intent of this chapter shall be met by incorporating the provisions of this chapter in facility operating procedures or as otherwise determined by management.

2-1.2

Administrative controls for changes in processes or equipment shall be developed to include fire protection concerns.

2-1.3

The administrative controls for facilities shall be reviewed and updated periodically.

2-2* Management Policy and Direction.

Corporate management shall establish policies and institute a program to promote life safety, the conservation of property, and the continuity of operations through provisions of fire prevention and fire protection measures at each facility.

2-3* Fire Hazards Analysis.

2-3.1

A documented fire hazards analysis shall be initiated early in the design process or when configuration changes are made to ensure that the fire prevention and fire protection requirements of this standard have been evaluated. This evaluation shall consider the facility’s specific design, layout, and anticipated operating needs. The evaluation shall consider acceptable means for separation or control of hazards, the control or elimination of ignition sources, and the suppression of fires. (*See Chapter 3*.)

2-3.2*

For existing facilities, a documented fire hazards analysis shall be performed for all areas of the facility.

2-4 Fire Prevention Program.

A written fire prevention program shall be established and shall include the following:

(a) Fire safety information for all employees and contractors, including familiarization with fire prevention procedures, emergency alarms and procedures, and procedures for reporting a fire;

(b) Documented facility inspections conducted at least monthly, including provisions for remedial action to correct conditions that increase fire hazards;

(c) A description of the general housekeeping practices and the control of transient combustibles;

(d) Control of flammable and combustible liquids and gases in accordance with the applicable documents referenced in Chapter 5;

(e) Control of ignition sources, including, but not limited to, grinding, welding, and cutting;

NOTE: See NFPA 51B, *Standard for Fire Prevention in Use of Cutting and Welding Processes*.

(f)* Fire reports, including an investigation and a statement on the corrective action to be taken; and

NOTE: See NFPA 901, *Uniform Coding for Fire Protection*.

(g) The restriction of smoking to properly designated and supervised areas of the facility.

2-5 Testing, Inspection, and Maintenance.

2-5.1

Upon installation, all fire protection systems shall be inspected and tested in accordance with the applicable documents referenced in Chapter 4.

2-5.2

All fire protection systems and equipment shall be periodically inspected, tested, and maintained in accordance with NFPA 25, *Standard for the Inspection, Testing, and Maintenance of Water-Based Fire Protection Systems*, and the applicable documents referenced in Chapter 4.

2-5.3

Testing, inspection, and maintenance shall be documented by means of written procedures, with results and follow-up actions recorded. Specific acceptance criteria shall be provided for each operation.

2-6 Impairments.

2-6.1

A written procedure shall be established to address impairments to fire protection systems and shall include the following:

(a) Identification and tracking of impaired equipment,

(b) Identification of personnel to be notified, and

(c) Determination of needed fire protection and fire prevention measures.

2-6.2

Impairments to fire protection systems shall be as short in duration as practicable. If the impairment is planned, all necessary parts and personnel shall be assembled prior to removing the protection system(s) from service. When an unplanned impairment occurs, or when a system has discharged, the repair work or fire protection system restoration shall be expedited.

2-6.3

Once repairs are completed, tests shall be conducted to ensure proper operation and restoration of full fire protection equipment capabilities. Following restoration to service, those parties previously notified of the impairment shall be advised.

2-7* Fire Emergency Plan.

A written fire emergency plan shall be developed and shall include the following:

(a) Response to fire alarms and fire systems' supervisory alarms;

(b) Notification of personnel identified in the plan;

(c) Evacuation from the fire area of personnel not directly involved in fire-fighting activities;

(d)* Coordination with security forces, radiation protection personnel, and other designated personnel for the admission of public fire department and other emergency response agencies;

(e) Fire extinguishment activities, particularly those that are unique to the facility handling radioactive materials (*see Appendix B*);

NOTE: NFPA 600, *Standard on Industrial Fire Brigades*, and OSHA 1910.156, *Fire Brigades*, should be consulted for additional information.

(f) Requirements for periodic drills and exercises to verify the adequacy of the fire emergency plan, including practice sessions coordinated around previously developed valid emergency scenarios particular to the facility; and

(g) Fire prevention surveillance.

NOTE: See NFPA 601, *Standard on Guard Service in Fire Loss Prevention.*

2-8 Fire Emergency Organization.

2-8.1

A fire emergency organization shall be provided.

2-8.2

The size of the facility and its staff, the complexity of fire-fighting problems, and the availability and response time of a public fire department shall determine the composition of the fire emergency organization.

2-8.3

Fire emergency organizations shall conduct drills at least quarterly, and they shall be critiqued by competent individuals. The drill critique shall be documented, and recommendations for improvements shall be implemented. Practice sessions shall be coordinated around previously developed valid emergency scenarios particular to the facility.

Chapter 3 General Facility Design

3-1* Special Considerations.

Provisions to limit contamination shall be based on the fire hazards analysis. The design of facilities handling radioactive materials shall incorporate the following:

(a) Limits on areas and equipment subject to contamination; and

(b) Design of facilities, equipment, and utilities to facilitate decontamination.

3-2 Location with Respect to Other Buildings and within Buildings.

3-2.1

Facilities having quantities of radioactive materials that might become airborne in case of fire or explosion shall be located or segregated from other important buildings or operations.

3-2.2

Particular attention shall be given to the location of intakes and outlets of air-cleaning systems to reduce contamination potential.

3-3* Planning for Contamination Control.

The facility shall be designed to provide construction that confines a potential radiation contamination incident and shall include surface finishes that are easy to clean.

3-4* Fire Area Determination.

The facility shall be subdivided into separate fire areas as determined by the fire hazards analysis for the purposes of limiting the spread of fire, protecting personnel, and limiting the consequential damage to the facility. Fire areas shall be separated from each other by barriers with fire resistance commensurate with the potential fire severity.

3-5 Construction.

Buildings in which radioactive materials are to be used, handled, or stored shall be fire resistive or noncombustible (Type I or Type II in accordance with NFPA 220, *Standard on Types of Building Construction*).

3-6* Openings in Fire Barriers.

3-6.1*

All openings in fire barriers shall be protected consistent with the designated fire resistance rating of the barrier.

3-6.2

Fire doors and fire windows used in fire barriers shall be installed and maintained in accordance with NFPA 80, *Standard for Fire Doors and Fire Windows*.

3-7 Shielding.

Any permanent or temporary shielding materials shall be noncombustible.

Exception: Where noncombustible materials cannot be used, limited-combustible materials shall be used and appropriate fire protection measures shall be provided as determined by the fire hazards analysis.

3-8 Interior Finish.

3-8.1

Interior finish in areas processing or storing radioactive materials shall be noncombustible and, where practicable, shall be nonporous for ease of decontamination.

3-8.2

Interior finish in areas not critical to the processing of radioactive materials shall be Class A or

Class B in accordance with NFPA *101®, Life Safety Code®*.

3-9* Heating, Ventilating, and Air Conditioning.

3-9.1

The design of the ventilation shall be in accordance with NFPA 90A, *Standard for the Installation of Air Conditioning and Ventilating Systems;* NFPA 90B, *Standard for the Installation of Warm Air Heating and Air Conditioning Systems;* and NFPA 91, *Standard for Exhaust Systems for Air Conveying of Materials*.

NOTE: In addition, see NFPA 204M, *Guide for Smoke and Heat Venting*.

Exception: Where shutdown of the ventilation system is not permitted, fire dampers shall not be required for ventilation duct penetrations. Alternative means of protecting against fire propagation shall be provided.

3-9.2

The ventilation system shall be arranged such that the area containing dispersible radioactive materials remains at a lower pressure than that of adjoining areas of the facility before and during any fire incident, including during and following any actuation of fire protection systems.

3-9.3

Duct work from areas containing radioactive materials passing through nonradioactive areas shall be of noncombustible construction and shall be protected from possible exposure fires by materials having an appropriate fire resistance rating as determined by the fire hazards analysis.

3-9.4

Self-cleaning filters that pass through a viscous liquid generally yield a radioactive sludge requiring disposal and, therefore, shall be avoided, if possible, in areas where radioactive materials are handled. Because of the combustible nature of the liquid, additional fire protection features shall be provided as determined by the fire hazards analysis.

3-9.5

Roughing filters, where necessary, shall be constructed of noncombustible materials.

Exception: Where combustible filters or particulates are present in the ventilation system, additional fire protection features shall be provided as determined by the fire hazards analysis.*

3-9.6 HEPA Filtration Systems.

3-9.6.1 All HEPA filtration systems shall be analyzed in the fire hazards analysis.

3-9.6.2* HEPA filtration systems with a leading surface area greater than 16 ft^2 (1.49 m^2) shall be provided with fire detection and suppression systems.

3-9.7 Smoke Control.

3-9.7.1* Fresh-air inlets shall be located to reduce the possibility of radioactive contaminants being introduced. Such inlets shall be located where it is most unlikely for radioactive contaminants to be present.

3-9.7.2 Smoke, corrosive gases, and the nonradioactive substances that might be freed by a fire shall be vented from their place of origin directly to a safe location. Radioactive materials that are released by fire shall be confined, removed from the exhaust ventilation airstream, or released under controlled conditions.

3-9.7.3 Ventilation systems designed to exhaust smoke or corrosive gases shall be evaluated to ensure that inadvertent operation or failures shall not violate the controlled areas of the facility design.

3-9.7.4 Smoke control systems shall be provided for fire areas based upon the fire hazards analysis.

NOTE: Separate smoke control systems are preferred; however, smoke ventilation can be integrated into normal ventilation systems using automatic or manually positioned dampers and motor speed control.

3-9.7.5 Smoke exhaust from areas that at any time contain radioactive substances shall not be ventilated outside the building. Smoke control systems for such areas shall be connected to treatment systems to preclude release of radioactive substances.

3-9.7.6 Enclosed stairwells shall be designed to minimize smoke infiltration during a fire.

NOTE: Stairwells serve as escape routes and fire-fighting access routes. Suitable methods of ensuring a smoke-free stairwell include pressurization of stairwells (*see NFPA 90A, Standard for the Installation of Air Conditioning and Ventilating Systems*) and the construction of smokeproof towers. (*See NFPA 101, Life Safety Code*.)

3-9.7.7 Where natural-convection ventilation is used, the smoke and heat ventilation shall be provided in accordance with the fire hazards analysis.

NOTE: Where mechanical ventilation is used, 300 cfm (8.5 m^3/min) is equal to 1 ft^2 (0.09 m^2) of natural-convection vent area.

3-9.7.8* The ventilation system shall be designed, located, and protected such that airborne corrosive products or contamination shall not be circulated.

3-9.7.9 The power supply and controls for mechanical ventilation systems shall be located outside the fire area served by the system or protected from fire damage.

3-9.7.10 Fire suppression systems shall be installed to protect filters that collect combustible material, unless the elimination of such protection is justified by the fire hazards analysis.

3-10 Drainage.

CAUTION: For facilities handling fissionable materials, areas where water can accumulate shall be analyzed for criticality potential.

3-10.1*

Provisions shall be made in all fire areas of the facility for removal of all liquids directly to safe areas or for containment within the fire area in order to reduce the potential for flooding of equipment and adverse impact on other areas. Drainage and the prevention of equipment flooding shall be accomplished by one or more of the following:

(a) Floor drains;

(b) Floor trenches;

(c) Open doorways or other wall openings;

(d) Curbs for containing or directing drainage;

(e) Equipment pedestals; or

(f) Pits, sumps, and sump pumps.

3-10.2 Drainage Design.

3-10.2.1 The provisions for drainage in areas handling radioactive materials and in any associated drainage facilities (pits, sumps, and sump pumps) shall be sized to accommodate all of the following:

(a) The spill of the largest single container of any flammable or combustible liquids in the area;

(b) The credible volume of discharge (as determined by the fire hazards analysis) for the suppression system operating for a period 30 min where automatic suppression is provided throughout;

(c) The volume based on a manual fire-fighting flow rate of 500 gpm (1892.5 L/min) for a duration of 30 min where automatic suppression is not provided throughout, unless the fire hazards analysis demonstrates a different flow rate and duration;

(d) The contents of piping systems and containers that are subject to failure in a fire where automatic suppression is not provided throughout; and

(e) Credible environmental factors such as rain and snow where the installation is outside.

3-10.2.2 Radioactive or potentially radioactive drainage piping shall not be routed through clean areas.

3-10.3

Floor drainage from areas containing flammable or combustible liquids shall be trapped to prevent the spread of burning liquids beyond the fire area.

3-10.4

Where gaseous fire suppression systems are installed, floor drains shall be provided with adequate seals, or the fire suppression system shall be sized to compensate for the loss of fire suppression agent through the drains.

3-11 Emergency Lighting.

3-11.1

Emergency lighting shall be provided for means of egress in accordance with NFPA *101*, *Life Safety Code*.

3-11.2

Emergency lighting shall be provided for critical operations areas, i.e., areas where personnel might be required to operate valves, dampers, and other controls in an emergency.

3-12 Lightning Protection.

Lightning protection, where required, shall be provided in accordance with NFPA 780, *Lightning Protection Code*.

3-13 Light and Power.

3-13.1*

An auxiliary power system shall be available to supply power for temporary lighting, ventilation, and radiation monitoring equipment in those facilities where the radioactive materials being handled are potentially dangerous to personnel.

3-13.2*

Electrical conduits leading to or from radioactively "hot" areas shall be sealed internally to prevent the spread of radioactive materials. Only utilities required for operation within radioactively "hot" areas shall enter the hot area.

3-13.3

Less hazardous dielectric fluids shall be used in place of hydrocarbon-based insulating oils for transformers and capacitors located inside buildings or where they are an exposure hazard to important facilities.

3-13.4

All electrical systems shall be installed in accordance with NFPA 70, *National Electrical Code*®.

3-14 Storage.

3-14.1 General.

Chemicals, materials, and supplies shall be in separate storerooms located in areas where no work with radioactive materials is conducted.

Exception: Those quantities of chemicals, materials, and supplies needed for immediate or continuous use.

3-14.2 Storage of Radioactive Materials.

3-14.2.1 Radioactive materials shall not be stored in the same area as combustible materials. Separate or remotely located noncombustible storage facilities shall be used to store radioactive materials safely.

3-14.2.2* Special consideration shall be given to the storage of radioactive compressed gases, as their release under fire or explosion conditions can result in a severe life safety threat and loss by contamination. Storage facilities for such gases shall be designed with special consideration given to the specific characteristics of the gases.

3-14.2.3* Care shall be exercised in selecting the locations for the storage of radioactive waste material. Such material shall not be located near the fresh-air intakes to the heating, ventilation, and air conditioning systems nor the air intakes for air compressors.

Chapter 4 General Fire Protection Systems and Equipment

4-1* General Considerations.

4-1.1

A fire hazards analysis shall be conducted to determine the fire protection requirements for the facility.

4-1.2

Automatic sprinkler protection provides the best means for controlling fires and shall be provided unless the hazards analysis in Section 2-3 dictates otherwise. As determined by the fire hazards analysis, special hazards shall be provided with additional fixed protection systems.

4-1.3*

For locations where fissile materials might be present that could create a potential criticality hazard, combustible materials shall be excluded. If combustible materials are unavoidably present in a quantity sufficient to constitute a fire hazard, water or another suitable extinguishing agent shall be provided for fire-fighting purposes. Fissile materials shall be arranged such that neutron moderation and reflection by water shall not present a criticality hazard.

4-2 Water Supply.

4-2.1* General.

4-2.1.1 The water supply for the permanent fire protection installation shall be based on the largest fixed fire suppression system(s) demand, including the hose stream allowance, in accordance with NFPA 13, *Standard for the Installation of Sprinkler Systems*.

4-2.1.2 For common service water/fire protection systems, the maximum anticipated service water demand shall be added to the fire protection demand.

4-2.1.3 The fire protection water supply system shall be arranged in conformance with NFPA 20, *Standard for the Installation of Centrifugal Fire Pumps;* NFPA 22, *Standard for Water Tanks for Private Fire Protection;* and NFPA 24, *Standard for the Installation of Private Fire Service Mains and Their Appurtenances*, as applicable.

4-2.2

Where an auxiliary supply is required by the fire hazards analysis, each supply shall be capable of meeting the requirements of 4-2.1.

4-2.2.1 Where multiple fire pumps are required, the pumps shall not be subject to a common failure, electrical or mechanical, and shall be of sufficient capacity to meet the fire flow requirements determined by 4-2.1 with the largest pump out of service.

4-2.2.2* Fire pumps shall be automatic-starting with manual shutdown. The manual shutdown shall be at the pump controllers only.

NOTE: For unattended facilities, see Section 4-9.

4-2.2.3* If tanks are for dual-purpose use, they shall be arranged to provide the water supply requirements as determined by 4-2.1 for fire protection use only.

4-2.2.4* Where water tanks are used, they shall be filled from a source capable of replenishing the supply for the fire protection needs of an 8-hour period.

4-2.3

If multiple water supplies are used, each water supply shall be connected to the fire main by separate connections that are arranged and valve controlled to minimize the possibility of multiple supplies being impaired simultaneously.

4-3* Valve Supervision.

All fire protection water system control valves shall be monitored under a periodic inspection program (*see Chapter 2*) and shall be supervised by one of the following methods:

(a) Electrical supervision with audible and visual signals on the main fire control panel or at another constantly attended location in accordance with NFPA 72, *National Fire Alarm Code;* or

(b) Valves locked open with keys available only to authorized personnel.

4-4 Supply Mains and Hydrants.

4-4.1

Supply mains and fire hydrants as required by the fire hazards analysis shall be installed on the facility site in accordance with NFPA 24, *Standard for the Installation of Private Fire Service Mains and Their Appurtenances*.

4-4.1.1 Where required by the fire hazards analysis, the supply mains shall be looped and of sufficient size to supply the flow requirements as determined by 4-2.1.

4-4.1.2 Indicator control valves shall be installed to provide adequate sectional control of the fire main loop to minimize protection impairments.

4-4.2

Each hydrant shall be equipped with a separate shutoff valve located on the branch connection to the supply main.

4-5 Standpipe and Hose Systems.

4-5.1

Standpipe and hose systems shall be installed in accordance with NFPA 14, *Standard for the Installation of Standpipe and Hose Systems*.

4-5.2

Hose station location shall take into account safe egress for personnel operating hose lines.

4-5.3

Spray nozzles having shutoff capability and listed for use on electrical equipment shall be provided on hoses located in areas near energized electrical equipment.

4-6 Portable Fire Extinguishers.

Suitable fire extinguishers shall be installed in accordance with NFPA 10, *Standard for Portable Fire Extinguishers*.

4-7 Fire Suppression Systems and Equipment.

4-7.1*

Fire suppression systems and equipment shall be provided in all areas of a facility as determined by the fire hazards analysis. Where required, the design of the fire suppression systems shall be in accordance with the following NFPA standards:

NFPA 11, *Standard for Low-Expansion Foam*

NFPA 11A, *Standard for Medium- and High-Expansion Foam Systems*

NFPA 12, *Standard on Carbon Dioxide Extinguishing Systems*

NFPA 12A, *Standard on Halon 1301 Fire Extinguishing Systems*

NFPA 12B, *Standard on Halon 1211 Fire Extinguishing Systems*

NFPA 13, *Standard for the Installation of Sprinkler Systems*

NFPA 14, *Standard for the Installation of Standpipe and Hose Systems*

NFPA 15, *Standard for Water Spray Fixed Systems for Fire Protection*

NFPA 16, *Standard on the Installation of Deluge Foam-Water Sprinkler and Foam-Water Spray Systems*

NFPA 17, *Standard for Dry Chemical Extinguishing Systems*

NFPA 17A, *Standard for Wet Chemical Extinguishing Systems*.

4-7.2

The selection of the extinguishing agent system shall be based upon:

(a) Type of hazard;

(b) Effect of agent discharge on equipment;

(c) Health hazards;

(d) Cleanup after agent discharge;

(e) Effectiveness of agent in suppressing fire;

(f) Cost of agent, including life cycle costs;

(g) Availability of agent;

(h) Criticality safety; and

(i) Environmental impact.

4-8 Fire Signaling Systems.

4-8.1

Fire detection and automatic fixed fire suppression systems shall be equipped with local audible and visual notification appliances with annunciation on the main fire control panel or at another constantly attended location in accordance with NFPA 72, *National Fire Alarm Code*.

4-8.2

Automatic fire detectors shall be installed in accordance with NFPA 72, *National Fire Alarm Code*, and as required by the fire hazards analysis.

4-8.3

The fire signaling system for the facility communications system shall provide the following:

(a) Manual fire alarm system by which employees can report fires or other emergencies,

(b) Facility-wide alarm system by which personnel can be alerted of an emergency,

(c) Two-way communications for the facility emergency organization if determined to be required by the fire hazards analysis (*see Sections 2-3 and 2-7*), and

(d) Means to notify the public fire department.

4-9* Unattended Facilities.

4-9.1

Additional fire protection measures shall be provided if the fire hazards analysis identifies that a delayed response or lack of communications in an unattended facility can result in a major fire spread prior to the arrival of fire-fighting personnel.

4-9.2

Remote annunciation of the fire-signaling panels shall be transmitted to one or more constantly attended locations.

Chapter 5 Special Hazards in Nuclear Facilities

5-1* General.

5-1.1

Combustion and safety controls and interlocks shall be tested periodically and after major maintenance activities in accordance with the equipment manufacturer's recommendations.

5-1.2

Flammable and combustible liquids shall be stored and handled in accordance with NFPA 30, *Flammable and Combustible Liquids Code*.

5-1.3

Flammable and combustible gases shall be stored and handled in accordance with NFPA 50, *Standard for Bulk Oxygen Systems at Consumer Sites;* NFPA 50A, *Standard for Gaseous Hydrogen Systems at Consumer Sites;* NFPA 54, *National Fuel Gas Code;* NFPA 55, *Standard for the Storage, Use, and Handling of Compressed and Liquefied Gases in Portable Cylinders;* and NFPA 58, *Standard for the Storage and Handling of Liquefied Petroleum Gases*.

5-1.4

Solid and liquid oxidizing agents shall be stored and handled in accordance with NFPA 43A, *Code for the Storage of Liquid and Solid Oxidizers*.

5-1.5

Combustible metals shall be stored and handled in accordance with NFPA 480, *Standard for the Storage, Handling, and Processing of Magnesium Solids and Powders;* NFPA 481, *Standard for the Production, Processing, Handling, and Storage of Titanium;* and NFPA 482, *Standard for the Production, Processing, Handling, and Storage of Zirconium*.

5-1.6

Fire protection for laboratories involved with radioactive materials shall be in accordance with NFPA 45, *Standard on Fire Protection for Laboratories Using Chemicals*.

5-1.7

Ovens, furnaces, and incinerators involved with radioactive materials shall be in accordance with the requirements of NFPA 82, *Standard on Incinerators and Waste and Linen Handling Systems and Equipment;* NFPA 86, *Standard for Ovens and Furnaces;* NFPA 86C, *Standard for Industrial Furnaces Using a Special Processing Atmosphere;* and NFPA 86D, *Standard for Industrial Furnaces Using Vacuum as an Atmosphere*.

5-2* Hospitals.

The appropriate form of fire protection for areas where radioactive materials exist in hospitals shall be based on the fire hazards analysis. Additional precautions shall be taken as required if the radioactive materials are stored or used in ways that might cause them to be more susceptible to release from their containers.

5-3 Fuel Fabrication and Fuel Reprocessing Facilities.

5-3.1

Special hazards related to the fire problems associated with fuel fabrication facilities shall be controlled by at least one of the following:

(a) Location,

(b) Safe operating procedures,

(c) Fixed protection systems,

(d) Inerting, or

(e) Any other methods acceptable to the authority having jurisdiction.

5-3.2* Flammable and Combustible Liquids and Gases.

5-3.2.1 In enclosed spaces in which combustible gas could accumulate outside of the storage vessels, piping, and utilization equipment, combustible-gas analyzers that are appropriate to the specific gas shall be installed. The analyzer shall be set to alarm at a concentration no higher than 25 percent of the lower explosive limit.

5-3.2.2 Flammable and combustible liquids in enclosed spaces in which vapors could accumulate outside of the storage vessels, piping, and utilization equipment, shall be installed with combustible-vapor analyzers appropriate for the vapors generated. The analyzer shall be set to alarm at a concentration no higher than 25 percent of the lower explosive limit.

5-3.2.3 In addition to the requirements of NFPA 30, *Flammable and Combustible Liquids Code,* for bulk storage of major combustible or flammable liquid gas piping systems, the fire hazards analysis shall consider the need for automatic shutoffs, excess flow valves, or emergency vents as required.

5-3.2.4 Safety controls and interlocks for bulk-storage, major combustible or flammable liquid gas piping systems shall be tested periodically and tested after maintenance operations.

5-3.2.5 Piping for all hazardous gas systems shall be periodically leak-tested at least annually or as required by the equipment manufacturer.

5-3.2.6 Hydraulic fluids used in presses or other hydraulic equipment shall be the synthetic, fire-resistant (low-hazard) type.

5-3.3 Solvents.

5-3.3.1* Where a flammable or combustible solvent is used, it shall be handled in a system that does not allow uncontrolled release of vapors. Approved operating controls and limits shall be established. An approved fixed system for fire extinguishing shall be installed or its absence justified to the satisfaction of the authority having jurisdiction.

5-3.3.2* Solvent distillation and recovery equipment for flammable or combustible liquids shall be isolated from areas of use by 3-hour fire barriers.

5-3.4*

In order to ensure the safe operation of process evaporators, such as Plutonium Uranium Reduction and Extraction (PUREX), means shall be provided to prevent entry of excess quantities of water-soluble solvents into the evaporators.

5-3.5*

Operating controls and limits for the handling of pyrophoric materials shall be established to the satisfaction of the authority having jurisdiction. A supply of an appropriate extinguishing medium shall be available in all areas where fines and cuttings of such materials are present. (*See Section 5-1*.)

5-4 Hot Cells, Glove Boxes, Hoods, and Caves.

5-4.1

All glove boxes, hoods, cells, and caves shall be provided with a means of fire detection if used in the handling of pyrophoric materials, oxidizers, or organic liquids.

5-4.2*

Fire suppression shall be provided in all glove boxes, cells, hoods, and caves that might contain combustible metals or organic liquids in quantities that could cause a breach of integrity.

5-4.3 Hot Cells.

5-4.3.1 Hot cells shall be of noncombustible construction. Liquid-filled windows shall contain a noncombustible medium, such as zinc bromide solution.

5-4.3.2 Where hydraulic fluids are used in master slave manipulators, synthetic fire-resistant (low-hazard) hydraulic fluids shall be used.

5-4.3.3 Combustible concentrations inside the cells shall be kept to a minimum. Where combustibles are present, a fixed extinguishing system shall be installed in the cell. If explosive concentrations of gases or vapors are present, an inert atmosphere shall be provided, or the cell and ventilation system shall be designed to withstand pressure excursions.

5-4.3.4 Noncombustible filters shall be used, or a fire suppression system shall be provided. (*See also Section 4-7*.)

5-4.3.5 A documented daily housekeeping inspection shall be made for each hot cell.

5-4.4* Glove Boxes.

5-4.4.1 The glove box and window shall be of noncombustible construction.

5-4.4.2 The number of gloves shall be limited to the minimum necessary to perform the operations. When the gloves are not being used, they shall be tied outside the box. When the gloves are no longer needed for operations, the gloves shall be removed and glove port covers installed.

5-4.4.3 The concentration of combustibles shall be kept to a minimum. Where combustibles are present, a fire suppression system or fixed inerting system shall be provided. If fixed extinguishing systems are utilized, the internal pressurization shall be calculated in order to prevent gloves from failing or being blown off.

5-4.4.4 Fire dampers shall be provided between glove boxes that are operated in series.

5-4.4.5 Noncombustible filters shall be used, or a fire suppression system shall be provided.

5-4.4.6 A documented daily housekeeping inspection shall be made for each glove box.

Chapter 6 Referenced Publications

6-1

The following documents or portions thereof are referenced within this standard and shall be considered part of the requirements of this document. The edition indicated for each reference is the current edition as of the date of the NFPA issuance of this document.

6-1.1 NFPA Publications.

National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.

NFPA 10, *Standard for Portable Fire Extinguishers*, 1994 edition.

NFPA 11, *Standard for Low-Expansion Foam*, 1994 edition.

NFPA 11A, *Standard for Medium- and High-Expansion Foam Systems*, 1994 edition.

NFPA 12, *Standard on Carbon Dioxide Extinguishing Systems*, 1993 edition.

NFPA 12A, *Standard on Halon 1301 Fire Extinguishing Systems*, 1992 edition.

NFPA 12B, *Standard on Halon 1211 Fire Extinguishing Systems*, 1990 edition.

NFPA 13, *Standard for the Installation of Sprinkler Systems*, 1994 edition.

NFPA 14, *Standard for the Installation of Standpipe and Hose Systems*, 1993 edition.

NFPA 15, *Standard for Water Spray Fixed Systems for Fire Protection*, 1990 edition.

NFPA 16, *Standard on the Installation of Deluge Foam-Water Sprinkler and Foam-Water Spray Systems*, 1991 edition.

NFPA 17, *Standard for Dry Chemical Extinguishing Systems*, 1994 edition.

NFPA 17A, *Standard for Wet Chemical Extinguishing Systems*, 1994 edition.

NFPA 20, *Standard for the Installation of Centrifugal Fire Pumps*, 1993 edition.

NFPA 22, *Standard for Water Tanks for Private Fire Protection*, 1993 edition.

NFPA 24, *Standard for the Installation of Private Fire Service Mains and Their Appurtenances*, 1992 edition.

NFPA 25, *Standard for the Inspection, Testing, and Maintenance of Water-Based Fire Protection Systems*, 1992 edition.

NFPA 30, *Flammable and Combustible Liquids Code*, 1993 edition.

NFPA 43A, *Code for the Storage of Liquid and Solid Oxidizers,* 1990 edition.

NFPA 45, *Standard on Fire Protection for Laboratories Using Chemicals,* 1991 edition.

NFPA 50, *Standard for Bulk Oxygen Systems at Consumer Sites*, 1990 edition.

NFPA 50A, *Standard for Gaseous Hydrogen Systems at Consumer Sites*, 1994 edition.

NFPA 54, *National Fuel Gas Code*, 1992 edition.

NFPA 55, *Standard for the Storage, Use, and Handling of Compressed and Liquefied Gases in Portable Cylinders*, 1993 edition.

NFPA 58, *Standard for the Storage and Handling of Liquefied Petroleum Gases,* 1992 edition.

NFPA 70, *National Electrical Code*, 1993 edition.

NFPA 72, *National Fire Alarm Code*, 1993 edition.

NFPA 80, *Standard for Fire Doors and Fire Windows*, 1992 edition.

NFPA 82, *Standard on Incinerators and Waste and Linen Handling Systems and Equipment*, 1994 edition.

NFPA 86, *Standard for Ovens and Furnaces,* 1990 edition.

NFPA 86C, *Standard for Industrial Furnaces Using a Special Processing Atmosphere*, 1991 edition.

NFPA 86D, *Standard for Industrial Furnaces Using Vacuum as an Atmosphere*, 1990 edition.

NFPA 90A, *Standard for the Installation of Air Conditioning and Ventilating Systems,* 1993 edition.

NFPA 90B, *Standard for the Installation of Warm Air Heating and Air Conditioning Systems*, 1993 edition.

NFPA 91, *Standard for Exhaust Systems for Air Conveying of Materials*, 1992 edition.

NFPA *101*, *Life Safety Code*, 1994 edition.

NFPA 220, *Standard on Types of Building Construction,* 1992 edition.

NFPA 251, *Standard Methods of Fire Tests of Building Construction and Materials,* 1990 edition.

NFPA 252, *Standard Methods of Fire Tests of Door Assemblies,* 1990 edition.

NFPA 255, *Standard Method of Test of Surface Burning Characteristics of Building Materials*, 1990 edition.

NFPA 480, *Standard for the Storage, Handling, and Processing of Magnesium Solids and Powders*, 1993 edition.

NFPA 481, *Standard for the Production, Processing, Handling, and Storage of Titanium,* 1987 edition.

NFPA 482, *Standard for the Production, Processing, Handling, and Storage of Zirconium,* 1987 edition.

NFPA 780, *Lightning Protection Code*, 1992 edition.

NFPA 803, *Standard for Fire Protection for Light Water Nuclear Power Plants*, 1993 edition.

6-1.2 ASTM Publication.

American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103.

ASTM E136-1982, *Standard Test Method for Behavior of Materials in a Vertical Tube Furnace at 750°C*.

Appendix A Explanatory Material

This Appendix is not a part of the requirements of this NFPA document but is included for informational purposes only.

A-1-1.1

The objectives of this standard are to reduce personal hazards, provide protection from property damage, and minimize process interruption resulting from fire and explosion. Radioactive contamination might or might not be a factor in these risks.

A-1-2

The nature of radioactive materials is such that their involvement in fires or explosions can impede the efficiency of fire-fighting personnel, thus causing increased potential for damage by radioactive contamination.

Various types of emitted radiation are capable of causing damage to living tissue. In particular, fire conditions can cause the formation of vapors and smoke that contaminate the building of origin or neighboring buildings and outdoor areas. The fire protection engineer's main concern is to prevent the release or loss of control of these materials by fire or during fire extinguishment. This is especially important because radioactivity is not detectable by any of the human senses.

For additional requirements for light water nuclear power reactors, see NFPA 803, *Standard for Fire Protection for Light Water Nuclear Power Plants*, and the recommendations for research reactors described in NFPA 802, *Recommended Fire Protection Practice for Nuclear Research and Production Reactors*.

A-1-5 Definitions.

Combustible. The three terms used to describe the combustibility of materials — noncombustible, limited-combustible, and combustible — have specific definitions. When attempting to classify the combustibility of a material, ensure that the definitions of all three terms are thoroughly understood.

Limited-Combustible. The three terms used to describe the combustibility of materials — noncombustible, limited-combustible, and combustible — have specific definitions. When attempting to classify the combustibility of a material, ensure that the definitions of all three terms are thoroughly understood.

Noncombustible. The three terms used to describe the combustibility of materials — noncombustible, limited combustible, and combustible — have specific definitions. When attempting to classify the combustibility of a material, ensure that the definitions of all three terms are thoroughly understood.

A-2-1.1

Chapter 2 provides criteria for the development of administrative procedures and controls necessary for the execution of fire prevention and fire protection activities and practices for facilities handling radioactive materials.

A-2-2

Proper preventive maintenance of operating equipment as well as adequate facility personnel training are important aspects of a viable fire prevention program.

A-2-3 Fire Hazards Analysis.

A thorough analysis of the fire potential is necessary to incorporate adequate fire protection into the facility design. Integrated design of systems is necessary to ensure the safety of the facility and the operators from the hazards of fire and to protect property and continuity of production.

The following steps are recommended as part of the analysis procedure:

(1) Prepare a general description of the physical characteristics of the facilities that outlines the fire prevention and fire protection systems to be provided. Define the fire hazards that can exist, and state the loss-limiting criteria to be used in the design of the facility.

(2) List the codes and standards to be used for the design of the fire protection systems. Include the published standards of the National Fire Protection Association. Indicate specific sections and paragraphs.

(3) Define and describe the characteristics associated with potential fire for all areas that contain combustible materials, such as maximum fire loading, hazards of flame spread, smoke generation, toxic contaminants, and contributing fuels. Consider the use and effect of noncombustible and heat-resistant materials.

(4) List the fire protection system criteria and the criteria to be used in the basic design for such items as water supply, water distribution systems, and fire pump safety.

(5) Describe the performance criteria for the detection systems, alarm systems, automatic suppression systems, manual systems, chemical systems, and gas systems for fire detection, confinement, control, and extinguishment.

(6) Develop the design considerations for suppression systems and for smoke, heat, and flame control, combustible and explosive gas control, and toxic and contaminant control. Select the operating functions of the ventilating and exhaust systems to be used during the period of fire extinguishment and control. List the performance criteria for the fire and trouble annunciator warning systems and the auditing and reporting systems.

(7) Consider the qualifications necessary for personnel performing inspection checks and the frequency of testing needed to maintain reliable alarm, detection, and suppression systems.

(8) Use the features of building and facility arrangements and the structural design features to generally define the methods for fire prevention, fire extinguishing, fire control, and control of hazards created by fire. Fire barriers, egress, fire walls, and the isolation and containment features that should be provided for flame, heat, hot gases, smoke, and other contaminants should be carefully planned. Outline the drawings and list of equipment and devices that are needed to define the principal and auxiliary fire protection systems.

(9) Identify the dangerous and hazardous combustibles and the maximum quantities estimated to be present in the facility. Consider where these materials can be appropriately located in the

facility.

(10) Review the types of potential fires, based on the expected quantities of combustible materials, their estimated severity, intensity, duration, and the hazards created. For each of the types reviewed, indicate the total time involved and the time for each step from the first alert of the fire hazard until safe control and extinguishment is accomplished. Describe in detail the facility systems, functions, and controls that will be provided and maintained during the fire emergency.

(11) Define the essential electric circuit integrity needed during fire. Evaluate the electrical and cable fire protection, the fire confinement control, and the extinguishing systems that will be needed to maintain their integrity.

(12) Carefully review and describe the control and operating room areas and the protection and extinguishing systems provided for these areas. Do not overlook the additional facilities provided for maintenance and operating personnel, such as kitchens, maintenance storage, and supply cabinets.

(13) Analyze the available forms of back-up or public fire protection that can be considered for the installation. Review the back-up fire department, equipment, number of personnel, special skills, and training needed.

(14) List and describe the installation, testing, and inspection necessary during construction of the fire protection systems that demonstrate the integrity of the systems as installed. Evaluate the operational checks, inspection, and servicing needed to maintain such integrity.

(15) Evaluate the program for training, updating, and maintaining competence of the facility fire-fighting and operating crew. Provisions should be required to maintain and upgrade the fire-fighting equipment and apparatus during facility operation.

(16) Review the qualifications for the fire protection engineer or consultant who will assist in the design and selection of equipment. This individual will also inspect and test the physical features of the completed system and develop the total fire protection program for the operating facility.

(17) Evaluate life safety, protection of critical process/safety equipment, provisions to limit contamination, potential for radioactive release, and restoration of the facility after a fire.

A-2-3.2

A fire risk analysis might also be required to be performed.

A-2-4

(f) Refer to Figure A-2-4(f).

Name of company: ____________________

Date of fire: ____________ Time of fire: ________ Operating facility: ______

Under construction: ____________________

Location where fire occurred: ____________________

Description of facility, fire area, or equipment (include nameplate rating) involved: ________

____

Cause of fire, such as probable ignition source, initial contributing fuel, equipment failure causing ignition, etc:

____

____

____

Story of fire, events, and conditions preceding, during, and after the fire: _________________

____

____

____

Types and approximate quantities of portable extinguishing equipment used: _______________

____

____

Was fire extinguished with portable equipment only? _________ Was public fire department called? ____

Employee fire brigade at this location? _______________ Qualified for incipient fires? ____

For interior structural fires? _______________________

Was fixed fire extinguishing equipment installed? ______________________________________

Specify type of fixed extinguishing system: ____

Automatic operation ___________ , manually actuated _____________ , or both _________

Specify type of detection devices: ____

Did fixed extinguishing system control _________ and/or extinguish fire? _________ or both? _______________________________________

Did detection devices and extinguishing system function properly? _______________________

If no, why? ____

____

Estimated direct damage due to fire: $ _________ , or, between $___________ and $ ____

Estimated additional (consequential) loss: $ ___________ Nature of additional loss: ______

____

____

Estimated time to complete repairs/replacement of damaged equipment/structure: __________

Number of persons injured: ________________ Number of fatalities: ______________

What corrective or preventive suggestions would you offer to others who may have similar equipment, structures, or extinguishing systems? ____________________________________

____

____

Submitted by: ____________________________ Title: ____________________________

Figure A-2-4(f) Sample fire report.

A-2-7

It is important that the responding fire brigade or public fire fighting forces be familiar with access, facility fire protection systems, emergency lighting, specific hazards, and methods of fire control.

A-2-7

(d) Using information provided by a health physicist, the level of radiation risk to be assumed should be decided by the officer in charge of the fire-fighting operation, based on the knowledge and importance of the operation to be accomplished.

A-3-1 Special Considerations.

The design and installation of service facilities such as light and power, heating and ventilation, storage, and waste disposal at facilities not handling radioactive materials might not present any unusual problems. The introduction of radioactive materials into a facility poses additional hazards to both personnel and property that warrant special consideration of these services. Inadequate attention to the design features of service facilities unfortunately has contributed to the extent of decontamination found to be necessary following fires and explosions. It is considered good practice to analyze the design of each service for the purpose of determining the effect the service would have upon the spread of contamination following a fire or criticality accident. An appraisal of the severity of contamination spread then can be used to determine the necessity for modifying the design of the service facility under consideration.

A-3-3 Planning for Decontamination.

The extent to which decontamination might be necessary depends upon the amount of radioactive material being released, its half-life, its chemical and physical form, and the type of radiation emitted. Taking all of these factors into account, a realistic assumption should be made as to the extent of a possible contamination incident. When decontamination is necessary, it can be costly and time consuming. These factors tend to raise costs and therefore justify capital expenditures to reduce them to a minimum through good emergency planning procedures.

A-3-4

Determination of fire area boundaries should be based on consideration of the following:

(a) Types, quantities, density, and locations of combustible material and radioactive materials;

(b) Location and configuration of equipment;

(c) Consequences of losing equipment;

(d) Location of fire detection and suppression systems; and

(e) Personnel safety/exit requirements.

It is recommended that most fire barriers separating fire areas be of 3-hour fire resistance rating unless a fire hazards analysis indicates otherwise. If a fire area is defined as a detached structure, it should be separated from other structures by an appropriate distance (*see NFPA 80A, Recommended Practice for Protection of Buildings from Exterior Fire Exposures*). Fire area boundaries typically are provided as follows:

(a) To separate manufacturing areas and radioactive materials storage areas from each other and from adjacent areas;

(b) To separate control rooms, computer rooms, or combined control/computer rooms from adjacent areas. Where a control room and computer room are separated by a common wall, the wall might not be required to have a fire resistance rating;

(c) To separate rooms with major concentrations of electrical equipment, such as switchgear rooms and relay rooms, from adjacent areas;

(d) To separate battery rooms from adjacent areas;

(e) To separate a maintenance shop(s) from adjacent areas;

(f) To separate the main fire pump(s) from the reserve fire pump(s), where these pumps provide the only source of water for fire protection;

(g) To separate fire pumps from adjacent areas;

(h) To separate warehouses and combustible storage areas from adjacent areas;

(i) To separate emergency generators from each other and from adjacent areas;

(j) To separate fan rooms and plenum chambers from adjacent areas; and

(k) To separate office areas from adjacent areas.

A-3-6

Penetration seals provided for electrical and mechanical openings should be listed or should meet the requirements of ASTM E814, *Fire Tests of Through-Penetration Fire Stops*, or UL 1479, *Fire Tests of Through-Penetration Fire Stops*.

A-3-6.1

Fire barriers also might be permitted to serve as radiation shields, HVAC air envelopes, or flood or watertight enclosures, and these concerns also should be taken into consideration.

A-3-9

Ventilation of a nuclear facility involves balanced air differentials between building areas, comfort ventilation, and heat removal from areas where heat is generated by equipment. This need also includes fire area isolation and smoke removal equipment, as well as equipment for filtering radioactive gases.

A-3-9.1

If plastic ducts are used, they should be listed fire retardant types and should be evaluated in the fire hazards analysis.

A-3-9.5 Exception.

The use of filters of low combustibility, such as those that comply with UL 586, *Standard for Test Performance of High Efficiency Particulate, Air Filter Units*, and UL 900, *Standard for Test Performance of Air Filter Units*, is recommended. Their use reduces the likelihood of the spread of contamination by fire. In the absence of protection systems within the ducts and for the filter banks, fires in combustible filters become extremely difficult to extinguish.

A-3-9.6.2 HEPA filtration systems with a leading surface area of 16 ft^2 (1.49 m^2) or less can be provided with fire detection and suppression systems to preclude the filter media being damaged by hot gases and flames.

A-3-9.7.1 For example, fresh-air inlets should not be located near storage areas of combustible radioactive waste material that, upon ignition, could discharge radioactive combustion products that might be picked up by the ventilating system.

A-3-9.7.8 A breakdown in an air-cleaning system can be more serious if the discharged air can be drawn immediately into another system. General isolation of radiation facilities from all other facilities causes an increase in both construction and operating costs but should be undertaken if justified by a study of the possible results of a contamination incident. In order to avoid unnecessary accidents, such facilities should be located separately from those handling explosives or flammable materials.

A-3-10.1

For further information, see NFPA 15, *Standard for Water Spray Fixed Systems for Fire Protection*, Appendix A.

A-3-13.1

The lights, ventilation, and operation of much remote-controlled equipment are dependent upon a reliable source of electrical power. The location of transformers, switches, and control panels should be well-removed from high-activity areas to ensure that maintenance work can be done without direct exposure to radiation from such areas. The need for effective ventilation during and immediately after an emergency such as a fire is of considerable importance.

A-3-13.2

It is important that electrical equipment be selected for its ease of decontamination and early restoration to service in those areas where a contamination is considered likely.

A-3-14.2.2 Special noncombustible storage facilities located remotely from the main facility might be necessary in some cases.

A-3-14.2.3 If the products of combustion of waste materials containing long-lived and highly active radioactive materials are dispersed through heating, ventilation, and air conditioning or compressed air systems, a decontamination problem of serious magnitude could result.

A-4-1

The facilities covered in this document vary widely in terms of function and the type of operations, as well as the type and quantity of radioactive material that might be present. The intent of this section is to specify the fire protection requirements for only those fire areas (or the whole) of the facility where radioactive materials are present.

A-4-1.3

In handling fissile materials, precautions should be taken not only to protect against the normal radiation hazard but also against the criticality hazard caused by the assembly of a minimum critical mass. To avoid criticality during fire emergencies, fissile materials that have been arranged to minimize the possibility of a criticality hazard should be moved only if absolutely necessary. If it becomes necessary to move such fissile materials, it should be done under the direction of a responsible person on the staff of the facility and in batches that are below the critical mass, or the materials shall be moved in layers that minimize the possibility of a criticality occurring. Since water is a reflector and a moderator of neutrons, concern for a criticality hazard sometimes leads to the unjustified and unevaluated exclusion of fire protection water from the area where fissile materials are stored or handled. The possibility of water moderation and reflection causing a criticality accident can be calculated in advance. If, in fact, such a hazard exists, combustible material that would necessitate the use of water for fire fighting should be eliminated. In many facilities, fissile materials are stored and handled in sprinklered areas.

A-4-2.1

Water quality can present long-term problems related to fire protection water supply. Factors to be considered should include water hardness, corrosiveness, presence of micro-organisms, and other problems that are unique to the type of facility.

A-4-2.2.2 For further information, see NFPA 20, *Standard for the Installation of Centrifugal Fire Pumps*.

A-4-2.2.3 For further information, see NFPA 22, *Standard for Water Tanks for Private Fire Protection*.

A-4-2.2.4 The 8-hour requirement for refilling can be extended if the initial supply exceeds the recommendations of 4-2.1. It normally is preferred for the refilling operation to be accomplished on an automatic basis.

A-4-3

All fire protection water system control valves should be supervised as recommended in NFPA 26, *Recommended Practice for the Supervision of Valves Controlling Water Supplies for Fire Protection*.

A-4-7.1

For the design of closed-head foam-water sprinkler systems, see NFPA 16A, *Standard for the Installation of Closed-Head Foam-Water Sprinkler Systems*.

A-4-9

Facilities that are operated unattended or with minimal staffing present special fire protection concerns. Consideration should be given both to the delayed response time for the fire brigade or public fire-fighting personnel and to the lack of personnel available to alert others on-site to a fire condition.

A-5-1

The principal fire hazards encountered in special radiation facilities will vary with the particular occupancy. In general, the requirements of this standard apply to all facilities handling radioactive materials within the scope of the document. Special occupancy fire hazards associated with particular operations are described in this chapter along with the special fire protection methods that apply to those hazards, with the exception of hazards associated with nuclear power plants and nuclear research reactors.

A-5-2

Radioactive materials are used in hospitals for a variety of purposes, including biomedical tracers, disease therapy, and laboratory analysis. General fire protection requirements for hospitals should be in accordance with NFPA 99, *Standard for Health Care Facilities*.

Radioactive materials used in hospitals rarely constitute a fire hazard themselves. Most often, the fire hazard associated with these materials is contamination of personnel, equipment, buildings, or the environment as a result of fire damage to containers and the subsequent release of radioactive materials.

Biomedical Tracers. Radioactive solutions can be administered to a patient intravenously or orally. The movement of the solution, as traced by monitoring the radioactivity level in different parts of the body, indicates the rate of various metabolic processes or the flow rate of blood. By comparing research data on healthy individuals with that of those known to have specific diseases, a patient's condition can be diagnosed without surgery.

Disease Therapy. Radioactive solutions can be administered to a patient intravenously or orally. The solution is designed to concentrate in specific organs or diseased tissue. The irradiation of the organ or tissue by the concentrated solution can alter the functioning of the organ (such as the thyroid gland) or kill diseased tissue (such as certain cancer cells).

Laboratory Analysis. Radioactive materials in solutions of known concentration are frequently used for laboratory analysis.

A-5-3.2

Combustible gases, such as hydrogen, ethylene, propane, acetylene, and natural gas, present both fire and explosion hazards. They should be used only in accordance with operating controls and limits required by the applicable NFPA standards.

A-5-3.3.1 Where solvents are used in fuel processing, consideration should be given to using solvents with the lowest fire and explosion hazard consistent with the requirements of the process.

A-5-3.3.2 Explosion-relief panels should be provided for solvent recovery areas.

A-5-3.4

Where using nitric acid during scrap recovery, experience and experiments have confirmed that exothermic reactions of distinctive violence can occur between tributylphosphate and uranyl nitrate or between tributylphosphate and nitric acid, or both.

A-5-3.5

Fines and cuttings from materials such as zirconium constitute a pyrophoric hazard.

A-5-4.2

The preferred method of suppression is an automatic sprinkler system, although other methods of suppression also may be permitted where installed in accordance with the applicable NFPA standard.

A-5-4.4

The external radiation hazard present during fabrication of Uranium-235 fuel elements is of a low order. Uranium-233 and Plutonium-239 present severe inhalation hazards to personnel; therefore, an enclosed protection system should be required to be used. These systems are called glove boxes. They can be extensive, with an appreciable amount of glass, and can present unique fire protection problems. Under normal conditions, substantial protection can be provided against the existing radiation hazard. On the other hand, if a criticality incident should occur, the type and quantity of radiation emitted can create grave hazards to personnel. Even a small fire within a glove box can produce serious consequences if not controlled properly. Fire control systems and procedures for glove boxes should be carefully developed and implemented before the boxes are used. Generally, such protective systems are custom-designed for the specific application.

Appendix B Sources of Radiation — The Nature of the Fire Problem

B-1 General.

B-1.1

Radioactive materials are substances that spontaneously decay, emitting energetic rays or particles in the process. Certain radioactive elements occur in more than one form. The various forms are chemically identical but differ in their atomic weights and are called isotopes. Those that are radioactive are called radioactive isotopes (radioisotopes). It is possible for an element to have one or more nonradioactive (stable) isotopes and one or more radioactive isotopes (radionuclides). Each of the radioisotopes emits a definitive type or types of radiation. In discussing radioactive material, therefore, it is always necessary to use the terminology that identifies the particular isotope, such as Uranium-238 or, alternatively, 238 Uranium.

B-1.1.1 Some radioisotopes occur in nature and can be separated by various physical or chemical processes; others are produced in particle accelerators or nuclear reactors.

B-1.1.2 Emissions from radioactive materials cannot be detected directly by any of the human senses. Radioactive materials themselves present no unusual fire hazards, as their fire characteristics are no different from the fire characteristics of the nonradioactive form of the same element.

B-1.1.3 The presence of radioactive materials can complicate a fire-fighting situation by presenting hazards unknown to the fire fighter and causing real or wrongly anticipated hazards to fire fighters, which can inhibit normal fire-fighting operations. The dispersal of radioactive materials by fumes, smoke, water, or by the movement of personnel can cause a radiation contamination incident that can contribute significantly to the extent of damage, complicate cleanup and salvage operations, delay the restoration of normal operations, and affect personnel safety.

B-2 Fire Problems.

B-2.1

Facilities handling radioactive materials should be designed and operated with special recognition given to the properties of radioactive materials. The effects of the presence of radioactive substances on the extent of loss caused by fire or explosion include:

(a) Possible interference with manual fire fighting due to the fear of exposure of fire fighters to radiation.

(b) Possible increased delay in salvage work and in resumption of normal operations following fire, explosion, or other damage due to radioactive contamination and the subsequent need for decontamination of buildings, equipment, and materials.

(c) Possible increase in the total damage due to buildings and equipment contaminated beyond the point where they are usable.

B-2.2

Radioactive materials can be expected to melt, vaporize, become airborne, or oxidize under fire conditions. None of these alterations will slow or halt radioactivity. It is conceivable that certain radioactive materials under fire conditions might be converted to radioactive vapor or oxidized to a radioactive dust or smoke. This dust or smoke could be carried by air currents and subsequently deposited on other parts of the burning buildings or even on neighboring buildings or land. These aggravated loss and personal injury characteristics of radioactive materials justify a high degree of protection against fire and explosion at those facilities where these potential hazards exist. The use of least combustible building components and equipment is highly desirable in those areas where radioactive materials are to be stored or used. Some form of automatic protection, such as automatic sprinklers, is highly advantageous wherever combustibles are encountered. The installation of automatic extinguishing systems reduces the need for personnel exposure to possible danger, starts the fire control process automatically, sounds an alarm, and makes efficient use of the available water supply. However, caution should be exercised to ensure that the hazards of criticality and reactivity are considered.

B-2.3

Some commonly encountered radionuclides are pyrophoric (e.g., uranium, plutonium) and, as such, should be given special consideration. Radionuclides generate heat and might need to be cooled in storage; these also require special consideration.

B-2.4

In view of the possibility of the spread of radioactive materials during a fire, certain precautions and procedures should be incorporated into emergency planning for fire-fighting operations.

B-2.5

The property manager should keep the local fire department advised of the locations and general nature of radioactive materials available. Emergency planning is essential so that fire fighters can function at maximum efficiency without exposure to harmful radiation and without unwarranted fears of the radiation hazard that can inhibit the fire-fighting effort. Where criticality incidents or exposure to radioactive materials is possible, mutual aid arrangements should maximize the use of on-site expertise. Specific provision should be made where necessary by the property manager and the fire department for monitoring service, protective clothing, and respiratory protective equipment, the need for which should be determined by the nature of the specific hazard. The radiation hazard usually can be anticipated in emergency planning studies.

B-3 Radiation Hazards and Protection Methods.

B-3.1

Significant levels of radiation exposure can occur under emergency conditions and can cause acute injury or death. However, fire fighters should be aware that radiation exposures that are tolerable in the event of a fire or other accident, especially where rescue operations are warranted, are unacceptable on a regular basis.

B-3.2 Nature of the Hazard of Radioactivity.

In order that fire-fighting personnel understand how to protect themselves against dangerous amounts of radiation effectively, it is necessary that they be familiar with the basic nature of radiation and the safeguards that generally are provided under normal operating conditions at those facilities where this hazard exists. While quite brief and simplified, the following paragraphs should assist the fire fighter in identifying those areas of concern:

(a) Radioactivity can be defined as the spontaneous emission of rays or particles during a change in an atom's nucleus. Radioactive decay is the spontaneous disintegration of a nucleus. Each radioactive isotope has a half-life — a period of time that is a characteristic of the particular isotope in which the intensity of nuclear radiation ascribable to that isotope progressively decreases by half. However, products formed by the radioactive decay of the original isotope can, in turn, be radioactive.

(b) The units for measuring the quantity of radioactivity in the source material are the curie, the millicurie (one one-thousandth curie), and the microcurie (one one-millionth curie). The term curie was originally designated as the standard for measuring the disintegration rate of radioactive substances in the radium family (expressed as 3.7×10^{10} atomic disintegrations per sec per gram of radium). It has now been adapted to all radioisotopes and refers to the amount of the isotope that has the same disintegration rate as 1 gram of radium.

Historically, the curie has been, and remains, the most commonly used unit for source strength. However, the SI unit for source strength is the becquerel. One becquerel is equal to one disintegration per sec. Hence, one curie is equal to 3.7×10^{10} becquerels.

(c) The sources of radiation likely to be encountered induce alpha particles, beta particles, gamma rays, and neutrons. The first three emit from many radioactive materials, and neutrons are likely to be present in the vicinity of nuclear reactors or accelerators only while reactors or accelerators are in operation, or they can emit from certain special neutron source materials. Neutrons, alpha particles, and beta particles are small bits of matter — smaller than an individual atom. Gamma rays (and x-rays) are electromagnetic radiations (similar to radio waves but with much shorter wavelengths).

(d) All radioactive emissions are capable of injuring living tissue. The fact that these radiations are not detectable by the senses makes them insidious, and serious injury can occur without an individual's awareness. Because of their relatively high penetrating power, gamma rays and neutrons can be a serious external hazard (i.e., potential severe danger even when from a source outside the body). Beta particles, which are less penetrating, can be somewhat of an external hazard if encountered within inches but are mainly an internal hazard; alpha particles, because of their extremely low penetrating power, are entirely an internal hazard (i.e., injure the body only if emanating from a source within the body after having entered the body by inhalation or ingestion or through a wound).

(e) These radiations are measured in roentgens, a unit representing the amount of radiation absorbed or the amount that will produce a specific effect. Radiation doses are measured in rems, a dose unit that will produce a specified effect in humans. The ultimate effect upon the human body depends on how and where the energy is expended. In industry, safeguards are provided for the purpose of keeping radiation exposure to personnel to a practical minimum and under certain amounts.

Historically, the roentgen and rem have been, and remain, the most commonly used units for radiation dosage. The current SI unit for dosage is the sievert. One sievert is equal to 100 rem. A sievert is equivalent to one joule per kilogram.

(f) In an emergency case, such as a necessary rescue operation, it is considered acceptable for the exposure to be raised within limits for single doses. The EPA 520/1-75-001, *Manual of Protective Action Guide and Protective Actions for Nuclear Incidents*, has recommended that, in a life-saving action, such as search for and removal of injured persons or entry to prevent conditions that would injure or kill numerous persons, the planned dose to the whole body should not exceed 75 rems. During circumstances that are less threatening to life, where it is still desirable to enter a hazardous area to protect facilities, to eliminate further escape of effluents, or to control fires, it is recommended that the planned dose to the whole body should not exceed 25 rems. These rules can be applied to a fire fighter for a single emergency; further exposure is not recommended. Internal radiation exposure by inhalation or ingestion can be guarded against by adequate respiratory equipment.

B-3.3 Personnel Protection Methods.

Monitoring is the process of measuring the intensity of radiation associated with a person, object, or area. It is done by means of instruments that can be photographic or electronic. Instruments used by personnel for radiation detection or measurement include:

(a) Film badge — a piece of photographic film that records gamma and beta radiation

(b) Pocket dosimeter — measures gamma radiation

(c) Geiger-Muller counter — measures beta and gamma radiation

(d) Scintillation counter — measures alpha, beta, and gamma radiation

(e) Ionization chamber — measures alpha, beta, and gamma radiation

(f) Proportional counter — measures alpha radiation

(g) Gamma survey meter — measures intensity of gamma radiation

(h) TLD (Thermoluminescent Dosimeter)   a crystal chip that records beta, gamma, and neutron radiation.

B-3.3.1 Common effects of excessive (200 roentgens or more) nuclear radiation on the body include vomiting, fever, loss of hair, loss of weight, decrease in the white blood cell count, and increased susceptibility to disease. Radioactive materials absorbed into the body often tend to accumulate at a particular location (e.g., plutonium and strontium tend to collect in the bone). The radioactivity concentrated in a particular organ gradually destroys the cell tissue so that the organ is no longer capable of performing its normal function, and the entire body suffers.

B-3.3.2 Radiation injury requires prompt, highly specialized treatment. Instruments should be provided to detect radiation contamination in clothing or on the skin. There should be a routine monitoring of the degree of exposure to the various particles and rays. Personnel working in the facility will generally be required to wear pocket radiation meters or indicators that are examined periodically, and records of the exposure should be kept for future reference.

B-3.3.3 The practice of placarding dangerous areas is for the protection of both regular operating personnel and those, such as fire fighters, who might have to deal with an emergency situation. If fire fighters are to have the best protection, they should inspect the premises where there might be radiation hazards to consider during fire operations well before a fire occurs. Also, by frequent follow-up inspections, they should reach an agreement with the emergency director or other personnel directing the facilities regarding steps to be taken in case of fire.

B-3.3.4 Fire fighters who might attend fires in properties where there are hazards of radioactivity should be given special training in proper protective clothing and cleanup or decontamination of their persons, clothing, or equipment. In all cases, they should have available and be trained in the use of suitable radiation monitoring equipment or have monitoring specialists with them.

B-3.4 Protection from External Radiation.

In the case of external nuclear radiation, the dosage and resulting injury to humans can be kept to a minimum in several ways:

(a) The smallest possible portion of the body only should be exposed (e.g., the hands, rather than the entire body).

(b) The time spent in the hazardous area and, therefore, the time of exposure, can be kept to a minimum by efficient organization of the work procedure.

(c) The intensity of radiation during exposure can be minimized by maintaining the greatest possible distance from the radiation source (e.g., by using long-handled tools for manipulating radioactive materials); or by the use of suitable materials interposed between the radiation source and the person to serve as a shield. Radiation intensity decreases inversely by an amount equal to the square of the distance from the source only where the source is a point source. This relationship is more complex with multiple point sources and does not apply to large sources until the distance is equal to one-half the maximum dimension of the source. Practically speaking, this could be 30 ft to 50 ft (9.1 m to 15.2 m). The cases in which a fire fighter will encounter a single point source are probably in the minority, and, therefore, the more conservative formula should be used.

B-3.5 Protection from Internal Radiation.

The possibility of radioactive materials entering the body can be reduced by wearing protective face masks and clothing while in a hazardous area. These masks should fit properly and be of a type that prevents the entry into the lungs or digestive system of the particular radioactive materials encountered. Clothing should be of such type to prevent the entry of radioactive materials into the body through wounds, scratches, or skin abrasions. Eating, drinking, smoking, and chewing should be prohibited while exposed to, or while awaiting decontamination after being in, radioactive areas.

B-3.5.1 Personnel working with radioisotopes are commonly subjected to routine biomedical checks for possible ingested radioactivity. Where applicable, routine checks also are made to verify that a permissible concentration of radioactive material in the body, the air, or elsewhere has not been exceeded.

B-3.5.2 Biomedical checks are promptly conducted whenever human ingestion of dangerous quantities of radioactive materials is suspected for any reason. When fire fighters are exposed to radiation and there is any doubt as to the severity of the exposure, they should be given a biomedical examination.

B-4 Sealed and Unsealed Radioactive Materials.

B-4.1

For purposes of this standard, a "sealed" radiation source is one that is tightly encapsulated (or the practical equivalent by bonding or other means) and is not intended to be opened at the facility. An "unsealed" source is one that is not so sealed or is intended to be opened at the facility, or both.

B-4.2

The protection of properties against the spread of radioactive contamination as the result of fire or explosion is simplified considerably by the fact that many radioactive materials are shipped, stored, and, in some cases, used, without ever exposing the radioactive material itself to air. In many cases the shipping containers, or even the use containers, might have sufficient integrity to withstand a fire or an external explosion. Examples include metallic cobalt-60 sources tightly encapsulated in steel and sealed sources used in "beta gauge" thickness and measuring devices. There have been several instances of stainless steel encapsulated beta gauge sources surviving appreciable fire exposures without release of the radioactive isotope contained therein.

B-4.3

The principal reason radioactive materials are sealed is to prevent spread of contamination. In some cases, the manufacturer of the container might not thoroughly consider fire resistance, and it is important to remember that a sealed source can burst if its contents are subject to thermal expansion as a result of exposure to fire.

B-4.4

Unsealed sources, such as can be found in laboratories during their transfer and use, can be spread about readily during a fire or an explosion.

B-5 Applications.

B-5.1

The specific application for ionizing radiation is governed somewhat by the physical makeup of its source, its sealed or unsealed form, and sometimes by its radiation intensity.

B-5.2

Most of the thousands of scientific and industrial uses of radioactive materials take advantage of one or more of the types of radiations emitted, i.e., alpha, beta, gamma rays, and neutrons. Certain radioisotope applications take advantage of the ultrasensitive detection capability of certain instruments for extremely small amounts of radioisotopes. Other uses take advantage of the ability of radiation to penetrate matter, while the extremely energetic sources have the ability to bring about biological, chemical, and physical changes.

B-5.3

The most common nuclear radiation applications can be grouped into the following categories:

(a) Radioisotope "tracer" applications utilize small amounts of short-lived, unsealed sources, involving easily detectable radiation emissions of the particular radioisotope employed. Such applications have found wide use in medical diagnosis, biological and agricultural explorations, water surveys, irrigation control, underground leak and seepage detection, atmospheric pollution, flow and transport rates in processing operations, lubrication and wear measurements, rapid chemical analysis for continuous process control, and activation analysis.

(b) Radioactive gauges and process control instruments utilize the more penetrating types of radiation from sources that are sealed to prevent the radioactive material from leaking. The radioactive material in no way enters into the system or process. This includes a wide range of operations, from measuring thickness or density to monitoring height and levels in storage and process equipment.

(c) Certain of the intensive sources of radiation have the ability to ionize gases. One of the important applications is the prevention of the accumulation of static electricity on moving machinery. The ionized air affects an "atmospheric grounding" and prevents buildup of static charges (radium and polonium as low-penetrating alpha emitters have been used, along with the more penetrating beta emitter, krypton-85). These sources also are being used as activating agents with self-luminous (phosphorescent) paints and coatings for various markings, emergency lighting, and instrument panels.

(d) Radioactive materials are being employed in the development of atomic batteries (as "isotopic power fuels"). The small currents generated are utilized in low-current demand micro-circuits; also, the liberation of thermal energy during radioisotope decay is converted into useful electricity through thermoelectric couples or thermionic systems. The sources include some fission products and some of the radioactive materials obtained by neutron irradiation of special target materials.

(e) Powerful sources are used in industrial radiography and nondestructive testing of critical process equipment. The leading industrially used isotope of high-energy emission is cobalt-60, which is obtained by the activation of cobalt in a reactor.

The industrial radiographer has a choice of x-ray machines or radioisotopes. In many cases, the latter offers the most advantages. The increased availability of cobalt-60 and iridium sources has resulted in radiographic inspections becoming commonplace. Steel thicknesses from $^1/_2$ in. to 6 in. (12.7 mm to 152 mm) can be evaluated radiographically, and many companies are now licensed to provide such examination services.

Other radioisotopes that have less energetic gamma ray emissions than cobalt-60 are coming into wider use for lighter materials such as aluminum, copper, zinc, and thin sections of steel.

(f) Powerful sources of high intensity radiation, such as cobalt-60, are used in food preservation and in radiological sterilization of pharmaceutical and medical supplies. Research and development indicate considerable promise in polymerization of plastics, vulcanization of rubber, improvement of wood properties, graft polymerization of plastics, and catalyzation of chemical reactions.

B-6 Nuclear Reactor Fuel Element Manufacture.

B-6.1

Certain radioactive nuclides are fissile. Neutrons absorbed by such nuclides emit additional neutrons plus energy, largely in the form of heat. Because more neutrons are emitted than are absorbed, a self-sustained nuclear chain reaction is possible when certain conditions are met. These conditions include a minimum quantity of fissile material (critical mass) and other factors such as shape, geometry, reflection, and moderation (or slowing of neutrons). Fissile materials used in a nuclear reactor are arranged in specific arrays using fuel elements in order to optimize conditions for fission to take place. When a nuclear chain reaction takes place where it was not intended, a criticality accident is said to have occurred.

B-6.2

In addition to the hazards of radiation and the potential for accidental criticality, fuel element manufacture often involves the use of combustible metals such as uranium and plutonium and combustible cladding material such as zirconium. The prevention of fires involving combustible metals requires special techniques. (*See NFPA 480, Standard for the Storage, Handling, and Processing of Magnesium Solids and Powders; NFPA 481, Standard for the Production, Processing, Handling, and Storage of Titanium; and NFPA 482, Standard for the Production, Processing, Handling, and Storage of Zirconium*.)

B-6.3

It is important to remember that nuclear fuel elements are extremely valuable, and extraordinary precautions can be necessary to protect them from the effects of an otherwise inconsequential fire.

B-7 Nuclear Fuel Reprocessing.

B-7.1

Reactors generally are capable of utilizing only a very small portion of the fuel contained in their elements, and, as a result, it is economical to recover the remaining fuel by processing the so-called “spent” elements in specially designed facilities. These facilities contain large quantities of radioactive materials (fission products) extracted from spent nuclear fuel elements that were produced as by-products during nuclear fission. Processing operations usually involve large quantities of flammable or corrosive liquids, or both. Fire and explosion hazards are present, and the possibility of an accidental criticality incident, although guarded against and remote, also is present.

B-7.2

The large quantities of highly radioactive materials present necessitate massive shielding for personnel safety, and most chemical processing and maintenance operations are conducted entirely by remote controls. Fire hazards are present during the sawing and chopping of fuel elements containing combustible metals, either in the form of fuel or cladding, and in the chemical processing operation. Specially designed fire detection and control systems are used to protect these operations. Ventilating systems should be arranged to maintain their integrity under fire conditions. Such facilities handling large quantities of highly radioactive materials demand the application of a high degree of fire protection planning in all areas.

B-8 Particle Accelerators.

B-8.1

Particle accelerators include Van de Graaff generators, linear accelerators, cyclotrons, synchrotrons, betatrons, and bevatrons. These machines are used, as their name implies, to accelerate the various charged particles that compose atoms to tremendous speeds and, consequently, to high energy levels. Radiation machines furnish scientists with atomic particles in the form of a beam that can be utilized for fundamental studies of atomic structure. In addition, they furnish high-energy radiation that can be utilized for radiography, therapy, or chemical processing.

B-8.1.1 These machines emit radiation only while in operation, and attempts to extinguish a fire in the immediate vicinity of the machine should be delayed until the machine power supply can be disconnected.

B-8.1.2 Certain "target" materials become radioactive when bombarded by atomic particles, and, for this reason, monitoring equipment should be used during fire-fighting operations to estimate the radiation hazard. The usual hazard presented by particle accelerators is largely that posed by electrical equipment. There are, however, some other significant hazards. Some installations have used such hazardous materials as liquid hydrogen, or other flammable materials, in considerable quantities. Large amounts of paraffin have been used for neutron shielding purposes, and the possible presence of combustible oils used for insulating and cooling is an additional hazard.

B-8.2

Industrial applications include chemical activation, acceleration of polymerization in plastics production, and the sterilization and preservation of packaged drugs and sutures. The general fire protection and prevention measures for these machines should include the use of noncombustible or limited-combustible (Type I or Type II) construction housing, noncombustible or slow-burning (*see IEEE-383, Standard for Type of Class IE Electric Cables, Field Splices and Connections for Nuclear Power Generating Stations*) wiring and interior finishing, and the elimination of as much other combustible material as possible (*see NFPA 220, Standard on Types of Building Construction*). Automatic sprinkler protection should be provided for areas having hazardous amounts of combustible material or equipment. Special fire protection should be provided for any high-voltage electrical equipment.

B-9 Isotope Production Facilities.

B-9.1 General.

Practical methods for production of radioactive isotopes include neutron activation of naturally occurring elements in reactors, fission of fissile material in reactors and extraction of radioactive fission products, and absorption of subatomic particles by atoms exposed in reactors or particle accelerators.

B-9.2 Isotope Production in Reactors.

Radioisotopes are produced in nuclear reactors by either bombardment of stable atoms with neutrons or other subatomic particles that cause transformation of the stable nucleus of the atom into an unstable or radioactive nucleus, or by separation of radioactive fission products from uranium used in the reactor.

B-9.2.1 Activation of isotopes in reactors generally is the result of the exposure of an element to a neutron flux resulting in a transmutation of the element due to neutron capture and alpha, beta, or proton decay. Fire hazards associated with reactor operations for this type of isotope production are described in NFPA 802, *Recommended Fire Protection Practice for Nuclear Research and Production Reactors*.

B-9.2.2 Various radioisotopes are produced as the result of fission of uranium in reactors. These isotopes can be removed from the fuel by chemical extraction following removal of the fuel from the reactor. Fire protection for reactor operations is described in NFPA 802, *Recommended Fire Protection Practice for Nuclear Research and Production Reactors*.

B-9.3 Radiation Machines.

Some radioisotopes are produced by exposing stable isotopes to high-energy subatomic particles. High-velocity subatomic particles are accelerated in particle accelerators such as Van de Graaff generators, linear accelerators, cyclotrons, or synchrotrons. These machines involve high-voltage electric and magnetic fields and produce radiation only while operating. Fire hazards associated with such machines are similar to any large electrical installation.

Appendix C Referenced Publications

C-1

The following documents or portions thereof are referenced within this standard for informational purposes only and thus are not considered part of the requirements of this document. The edition indicated for each reference is the current edition as of the date of the NFPA issuance of this document.

C-1.1 NFPA Publications.

National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.

NFPA 15, *Standard for Water Spray Fixed Systems for Fire Protection*, 1990 edition.

NFPA 16A, *Standard for the Installation of Closed-Head Foam-Water Sprinkler Systems*, 1994 edition.

NFPA 20, *Standard for the Installation of Centrifugal Fire Pumps*, 1993 edition.

NFPA 22, *Standard for Water Tanks for Private Fire Protection*, 1993 edition.

NFPA 26, *Recommended Practice for the Supervision of Valves Controlling Water Supplies for Fire Protection*, 1988 edition.

NFPA 30, *Flammable and Combustible Liquids Code*, 1993 edition.

NFPA 51B, *Standard for Fire Prevention in Use of Cutting and Welding Processes*, 1994 edition.

NFPA 80A, *Recommended Practice for Protection of Buildings from Exterior Fire Exposures*, 1993 edition.

NFPA 90A, *Standard for the Installation of Air Conditioning and Ventilating Systems*, 1993 edition.

NFPA 99, *Standard for Health Care Facilities*, 1993 edition.

NFPA *101*, *Life Safety Code*, 1994 edition.

NFPA 204M, *Guide for Smoke and Heat Venting*, 1991 edition.

NFPA 220, *Standard on Types of Building Construction*, 1992 edition.

NFPA 480, *Standard for the Storage, Handling, and Processing of Magnesium Solids and Powders*, 1993 edition.

NFPA 481, *Standard for the Production, Processing, Handling, and Storage of Titanium*, 1987 edition.

NFPA 482, *Standard for the Production, Processing, Handling, and Storage of Zirconium*, 1987 edition.

NFPA 600, *Standard on Industrial Fire Brigades*, 1992 edition.

NFPA 601, *Standard on Guard Service in Fire Loss Prevention*, 1992 edition.

NFPA 802, *Recommended Fire Protection Practice for Nuclear Research and Production Reactors*, 1993 edition.

NFPA 803, *Standard for Fire Protection for Light Water Nuclear Power Plants*, 1993 edition.

NFPA 901, *Uniform Coding for Fire Protection*, 1990 edition.

C-1.2 Other Publications.

C-1.2.1 ASTM Publications. American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19105.

ASTM E380, *Standard Practice for Use of the International System of Units*, Rev A-89.

ASTM E814, *Fire Tests of Through-Penetration Fire Stops*, 1988 edition.

C-1.2.2 EPA Publication. Environmental Protection Agency, 401 M Street SW, Washington, DC 20460.

EPA 520/1-75-001, *Manual of Protective Action Guide and Protective Actions for Nuclear Incidents*.

C-1.2.3 IEEE Publication. Institute of Electrical and Electronics Engineers, 345 East 47 Street, New York, NY 10070.

IEEE 383, *Standard for Type of Class IE Electric Cables, Field Splices and Connections for Nuclear Power Generating Stations*, 1974 edition.

C-1.2.4 OSHA Publication. Occupational Safety and Health Administration, 200 Constitution Avenue, NW, Washington, DC 20210.

OSHA 1910.156, *Fire Brigades*, 1981.

C-1.2.5 UL Publications. Underwriters Laboratories Inc., 333 Pfingsten Road, Northbrook, IL 60062.

UL 586, *Standard for Test Performance of High Efficiency Particulate, Air Filter Units*, sixth edition.

UL 900, *Standard for Test Performance of Air Filter Units*, fifth edition.

UL 1479, *Fire Tests of Through-Penetration Fire Stops*, 1983 edition.

Appendix D Additional Publications

This Appendix is not a part of the requirements of this NFPA document but is included for informational purposes only.

The following is a selection of additional reference materials.

The National Council on Radiation Protection and Measurement has issued a number of reports on specific radiation protection subjects. These reports are available from NCRP Publications, P.O. Box 4867, Washington, DC 20008, or from the U.S. Government Printing Office. Some applicable publications include:

NCRP 30, *Safe Handling of Radioactive Materials-NBS Handbook 92,* 1964.

NCRP 38, *Protection Against Neutron Radiation,* 1971.

NCRP 39, *Basic Radiation Protection Criteria,* 1971.

Standards of the U.S. Nuclear Regulatory Commission for protection against radiation are published in the *Code of Federal Regulations*, Part 20, Chapter 1, Title 10, available at most libraries. Revisions are printed in the Federal Register, available at subscribing libraries or by subscription from the U.S. Government Printing Office.

Nuclear Safety, a bimonthly magazine is available from the U.S. Government Printing Office. It covers many areas of interest, including general safety, accident analysis, operating experiences, and current events.

Specific requirements for facilities handling radioactive materials have been issued by the American Nuclear Insurers, Town Center, Suite 300S, 29 South Main Street, West Hartford, CT 06107-2445, and the MAERP Reinsurance Association, 1151 Boston-Providence Turnpike, Norwood, MA 02062.

NFPA 802

1993 Edition

Recommended Practice for Fire Protection for Nuclear

1993 Edition

This edition of NFPA 802, *Recommended Practice for Fire Protection for Nuclear Research and Production Reactors*, was prepared by the Technical Committee on Atomic Energy and acted on by the National Fire Protection Association, Inc. at its Fall Meeting held November 16-18, 1992, in Dallas, TX. It was issued by the Standards Council on January 15, 1993, with an effective date of February 12, 1993, and supersedes all previous editions.

The 1993 edition of this document has been approved by the American National Standards Institute.

Changes other than editorial are indicated by a vertical rule in the margin of the pages on which they appear. These lines are included as an aid to the user in identifying changes from the previous edition.

Origin and Development of NFPA 802

This recommended practice was tentatively adopted at the Annual Meeting in May 1958. As a result of suggestions received during the period of its circulation, new text was added in the sections on the Boiling Water Reactor and on Educational and Training Reactors, and it was adopted in May 1960, as revised.

A completely revised and updated edition was adopted in May 1974. Revisions in the 1983 edition included the substitution of ionizing in place of gamma to include other types of radiation to which one may be exposed. Changes to the 1988 edition included a caution to special problems that may be caused by graphite reactors.

The revisions to this latest edition include expanding the scope to cover production reactors and revising the title from *Recommended Fire Protection Practice for Nuclear Research Reactors* to *Recommended Practice for Fire Protection for Nuclear Research and Production Reactors*.

Technical Committee on Atomic Energy

Walter W. Maybee, *Chairman*
Los Alamos Nat'l Laboratories, NM

Wayne D. Holmes, *Secretary*
Professional Loss Control, Inc., PA

Mario A. Antonetti, Gage-Babcock & Assoc. Inc., NY

William G. Boyce, U.S. Department of Energy, DC

Ford W. Burgess, Westinghouse Savannah River Co., SC

Harry M. Corson IV, Cerberus Pyrotronics, NJ
Rep. Nat'l Electrical Mfr. Assn.

Donald A. Diehl, Alison Control Inc., NJ

Paul H. Dobson, Factory Mutual Research Corp., MA

Stewart M. Fastman, American Ins. Services Group Inc., NY

James F. Foley, New York Power Authority, NY

Paul Giaccaglia, American Nuclear Insurers, CT

Leonard R. Hathaway, M&M Protection Consultants, IL

LeRoy J. Hill, McDermott Inc., VA

L. S. Homa, Underwriters Laboratories Inc., IL

Donald J. Keigher, Los Alamos, NM

Jacob B. Klevan, Rolf Jensen & Assoc. Inc., VA

Thomas J. Kramer, Schirmer Engineering Corp., IL

Robert S. Levine, Nat'l Inst. of Standards & Technology, DC

Anthony J. Mascena, Stone & Webster Engineering Corp., NJ

J. Edward Maxwell, General Electric Co., CA

David P. Notley, U.S. Nuclear Regulatory Commission, DC

Robert J. O'Laughlin, Knoxville, TN

Mark Henry Salley, Tennessee Valley Authority, TN

Eric J. Shelton, Impell Corp., GA

Clifford R. Sinopoli, Baltimore Gas & Electric, MD
Rep. Electric Light Power Group/Edison Electric Inst.

Rupert M. H. Terrier, Virginia Electric & Power Co., VA

Lynn K. Underwood, Wausau Insurance Cos., WI

Rep. The Alliance of American Insurers

Steven F. Vieira, Grinnell Fire Protection Systems, RI
Rep. Nat'l Fire Sprinkler Assn.

Alternates

Daniel L. Arnold, Rolf Jensen & Assoc., VA
(Alt. to J. B. Klevan)

Ingemar B. Asp, Gage-Babcock & Assoc. Inc., NY
(Alt. to M. A. Antonetti)

James B. Biggins, M&M Protection Consultants, IL
(Alt. to L. R. Hathaway)

L. Paul Herman, Professional Loss Control, Inc., IL
(Alt. to W. D. Holmes)

Jimmy J. Pierce, Tennessee Valley Authority, TN
(Alt. to M. H. Salley)

George Ruetenik, American Nuclear Insurers, CT
(Alt. to P. Giaccaglia)

Gerald R. Schultz, Schirmer Engineering Corp., IL
(Alt. to T. J. Kramer)

Robert W. Strong, General Electric, CA
(Alt. to J. E. Maxwell)

Michael J. Vitacco, Jr., Westinghouse Savannah River Co., SC
(Alt. to F. W. Burgess)

Casey C. Grant, NFPA Staff Liaison

This list represents the membership at the time the Committee was balloted on the text of this edition. Since that time, changes in the membership may have occurred.

NOTE: Membership on a Committee shall not in and of itself constitute an endorsement of the Association or any document developed by the Committee on which the member serves.

Committee Scope: The safeguarding of life and property from fires in which radiation or other effects of nuclear energy might be a factor.

NFPA 802

Recommended Practice for

Fire Protection for Nuclear Research and Production Reactors

1993 Edition

NOTICE: Information on referenced publications can be found in Chapter 5 and Appendix A.

Chapter 1 Introduction

1-1 Scope.

1-1.1

This recommended practice covers the protection of life and property from the consequences of fire in nuclear reactor facilities other than those producing electricity.

1-1.2

Nuclear electric generating facilities are excluded, except for applicable and generic portions of NFPA 803 that relate to nuclear research and production reactors. (*See NFPA 803, Standard for Fire Protection for Light Water Nuclear Power Plants*.)

1-2 Purpose.

This recommended practice is prepared for the use and guidance of those charged with the design, construction, operation, and protection of nuclear research reactor facilities. It covers those requirements essential to assure that the consequences of fire will have minimum impact upon the safety of personnel, the physical integrity of the facility, and the continuity of operations.

1-3 General Information.

1-3.1 Power Level.

High power levels are generally associated with power reactors. Small units such as some package research reactors may pose problems due to their capability of being located in existing facilities or multiple occupancy buildings. While the maximum credible loss in nuclear terms may be much reduced, the fire exposure may actually be greater.

1-3.2 Coolants and Moderators.

These may run the gamut from simple water systems in pool reactors, to pumped water systems in boiling water reactors (BWR) or pressurized water reactors (PWR), or to circulating gas systems in high temperature gas reactors (HTGR). Particular fire protection problems are presented by liquid metal-cooled reactors, which generally use sodium systems. Particular fire protection problems may also be presented by liquid metal fast breeder reactors and graphite moderated reactors.

1-3.3 Fuel.

The susceptibility and quantity of the fuel material itself may be a factor. While uranium and plutonium are combustible metals, fuel elements composed of these metals generally use oxide fuels (in effect the fuel is already “burnt” and therefore incapable of combustion) but some reactors may use other forms, such as carbide, which may be pyrophoric. Even when such forms are not subject to fire exposure, such as in a water pool reactor, the manufacture, storage, and handling of the fuel may pose fire protection problems.

1-3.4 Shielding.

The nature of the shield material used for biological radiation protection varies from massive concrete to paraffin or wood-plastic compositions. Beyond the fuel contribution of some material, a fire burning or melting shielding can pose a radiation exposure problem to responding emergency forces.

1-3.5 Control Systems.

Reactor control systems and safety systems are of utmost importance. The control system design is fitted to the technical characteristics of the reactor and capable of producing power changes at acceptable rates. The control system design also makes it possible to produce and maintain the desired power level within the reactor in such a manner that excessive temperatures are avoided. The safety system also is adapted to the characteristics of the reactor and the instrument and control systems. It responds to signals from the instruments in such ways as to prevent, by automatic action, operational variables from exceeding safe limits. It also, on appropriate signals, warns of incipient changes in performance and, if necessary, shuts down the reactor.

1-3.5.1 Since the control system is vital to the adequate functioning and safe operation of the reactor, the protection of the control room, cableways, emergency power supply, and electrically or hydraulically operated equipment in general is of prime importance. Protection for the control room should be fully consistent with that for important computer rooms (*see NFPA 75, Standard for the Protection of Electronic Computer/Data Processing Equipment, or AEC Publication WASH 1245-1, Standard for Fire Protection of AEC Electronic Computer/Data Processing Systems*).

1-3.5.2 While comprehensive, automatic control systems are essential elements in reactor safety, the effectiveness of the total safeguards also depends on the proper execution of operating procedures that are technically sound and comprehensive.

1-3.6 Classification.

There is no single system of reactor classification. Reactors are generally classified by a combination name indicating one or more of its properties such as end-use, type of coolant or moderator, fuel form, neutron speed, and others. These are generally shortened to an acronym in common usage. Thus we have:

HTGR — High Temperature Gas Cooled Reactor

LMFBR — Liquid Metal Fast Breeder Reactor

1-3.7 Units.

Metric units of measurement in this recommended practice are in accordance with the modernized metric system known as the International System of Units (SI). One unit (liter), outside of but recognized by SI, is commonly used in international fire protection. If a value for measurement as given in this document is followed by an equivalent value in other units, the first stated is to be regarded as the requirement. A given equivalent value may be approximate.

1-4 Definitions.

Approved. Acceptable to the “authority having jurisdiction.”

NOTE: The National Fire Protection Association does not approve, inspect or certify any installations, procedures, equipment, or materials nor does it approve or evaluate testing laboratories. In determining the acceptability of installations or procedures, equipment or materials, the authority having jurisdiction may base acceptance on compliance with NFPA or other appropriate standards. In the absence of such standards, said authority may require evidence of proper installation, procedure or use. The authority having jurisdiction may also refer to the listings or labeling practices of an organization concerned with product evaluations which is in a position to determine compliance with appropriate standards for the current production of listed items.

Authority Having Jurisdiction. The “authority having jurisdiction” is the organization, office or individual responsible for “approving” equipment, an installation or a procedure.

NOTE: The phrase “authority having jurisdiction” is used in NFPA documents in a broad manner since jurisdictions and “approval” agencies vary as do their responsibilities. Where public safety is primary, the “authority having jurisdiction” may be a federal, state, local or other regional department or individual such as a fire chief, fire marshal, chief of a fire prevention bureau, labor department, health department, building official, electrical inspector, or others having statutory authority. For insurance purposes, an insurance inspection department, rating bureau, or other insurance company representative may be the “authority having jurisdiction.” In many circumstances the property owner or his designated agent assumes the role of the “authority having jurisdiction”; at government installations, the commanding officer or departmental official may be the “authority having jurisdiction.”

Labeled. Equipment or materials to which has been attached a label, symbol or other identifying mark of an organization acceptable to the “authority having jurisdiction” and concerned with product evaluation, that maintains periodic inspection of production of labeled equipment or materials and by whose labeling the manufacturer indicates compliance with appropriate standards or performance in a specified manner.

Listed. Equipment or materials included in a list published by an organization acceptable to the “authority having jurisdiction” and concerned with product evaluation, that maintains periodic inspection of production of listed equipment or materials and whose listing states either that the equipment or material meets appropriate standards or has been tested and found suitable for use in a specified manner.

NOTE: The means for identifying listed equipment may vary for each organization concerned with product evaluation, some of which do not recognize equipment as listed unless it is also labeled. The “authority having jurisdiction” should utilize the system employed by the listing organization to identify a listed product.

Shall. Indicates a mandatory requirement.

Should. Indicates a recommendation or that which is advised but not required.

Chapter 2 Reactor Safety Considerations

2-1 General.

While it is beyond the scope of this publication to discuss the entire range of problems associated with the operation of reactors, it is appropriate to enumerate a number of identifiable problems that have a specific bearing on fire protection.

2-2 Fire Control Problems Due to Radiation Effects.

2-2.1

It should be kept in mind that almost every nuclear reactor will have areas of intense radioactivity associated with it. In fire fighting operations, it is essential not to disturb any part of the structure that is provided for shielding from radiation. In many cases the targets are themselves radioactive and the shielding may be combustible.

2-2.2

During fuel element changes or when the reactor is opened, the potential for radiation exposure to personnel is increased. Specialized shielding equipment, remote handling devices, and protected storage casks or water pools are used to reduce to a minimum this potential for exposure.

2-2.3

There is always the possibility, under emergency conditions, that admittance of personnel to the area housing the reactor or process areas would be forbidden due to high radiation levels or due to radioactive materials in dust or vapors that would be dangerous to inhale or ingest. It is essential that complete preplanning be carried out between the public fire department and the reactor management: where and how and to what extent the public fire department would be called upon to function.

2-2.4

It is important that reactor operations management recognize that in those areas in which fire fighting forces may not be admitted under some accident situations, complete reliance must be placed on proper design, use of noncombustible materials, and built-in fixed protection.

2-2.5

The permissible radiation to which fire fighters and other emergency personnel may expose themselves is a subject on which no simple statement can be made. One kind of exposure comes from external exposure to ionizing radiation. Another comes from radioactive substances that may be inhaled or ingested.

2-2.6

The exact limits should be defined by the emergency program established for the particular installation. Limits for routine workers, as defined in NRC regulations applicable to NRC contractors and in the *Code of Federal Regulations*, Title 10, Part 20, applicable to NRC licensees, are based on continuing exposure at those levels for a working lifetime. It does not apply to emergency or once-in-a-lifetime exposure. There are no mandatory limits in this situation, although the Bureau of Standards Handbook 59 recommended a 25-rem emergency exposure limit without affecting the normally allowed accumulation rates for workers. Some facilities have adopted 50 rems as an emergency limit. On the other hand, the National Council on Radiation Protection Report No. 39, *Basic Radiation Protection Criteria*, suggests that under emergency conditions that involve lifesaving actions the planned whole body dose should not exceed 100 rems, and during other less urgent emergencies, such as fighting fires, the planned whole body dose should not exceed 25 rems. In emergency situations such as fire fighting, the actual exposures may be uncertain, and exposures should be controlled by the amount of good to be achieved, just as for any other hazard fire fighters are expected to face. The pertinent point is that the exposure that can be permitted in emergency situations can be many times the routine day-after-day exposure limits and not pose a threat to the life of the fire fighter.

2-2.7

The problem of internal radiation exposure is entirely different from the external exposure problem, and establishing limits for emergencies is impracticable in the face of measuring difficulties inherent in emergencies. This is really no different than the problem presented by trying to define inhalation limits for smoke, carbon monoxide, and other products of combustion. Fortunately, the mandatory use of self-contained breathing apparatus in radiation emergencies can materially reduce the problem. This problem is discussed more fully in the AEC publication *Living With Radiation, Part 1, Fundamentals*, and *Part 2, Fire Service Problems*.

2-2.8

Radioactive materials, like other particulate matter, may be transported in the smoke of a fire. If deposited on the body or clothing, it can create a potential exposure problem requiring decontamination procedures such as washdown, clothing removal, personnel showers, etc. Every facility should have procedures for decontaminating clothing, personnel, and equipment that may be exposed in emergency situations.

2-2.9

While many facilities provide, and require, special coveralls, shoe covers, etc., for all workers in the facility, it should be remembered that this is an administrative convenience for plant operations. It does not provide a level of radiation protection any greater than that provided by a fire fighter's turnout clothes. In no case should emergency response be delayed because of regulations intended for the administrative convenience of routine operations. Prefire planning should include recognition of such potential problem areas.

2-2.10

It is important that movement of personnel who may carry contamination from contaminated areas to uncontaminated areas be carefully controlled. Plans for such controls should be included in the facilities' emergency plans, and fire fighting forces should be indoctrinated in the emergency systems.

2-3 Accident Involving Fissionable Materials.

2-3.1

The fissionable materials, uranium-233 and -235 and plutonium, should be used with provisions to prevent the accidental assembly of fissionable material into critical masses.

2-3.2

Since water is a reflector and moderator of neutrons, it is theoretically possible that an arrangement of subcritical fissionable material could be made critical by the introduction of water. Storage containers, shelving, and storerooms are required to be designed to prevent the accidental assembly of a critical mass. In many cases, the areas are designed to be critically safe even when completely submerged in water. Emergency planning should include the effects of fire fighting water on such areas, assuming disruption of the contents by the accident or by fire hoses. If manual fire fighting poses a potential hazard under the worst conditions, then it is essential that any required fire-extinguishing capability be self-contained and automatic in operation.

2-3.3

If, during a fire, an assembly of fissionable material should become critical, it could not explode like an atomic bomb since special conditions are necessary for such an explosion. Experience to date has shown that such reactions have been self-limiting, but do result in minor distribution of radioactive products over the immediate area accompanied by a brief, very intense burst of nuclear radiation that could be lethal.

2-3.4

Reactors are normally loaded with a quantity of nuclear fuel greater than the minimum necessary to obtain an initial self-sustaining nuclear reaction. If loss of cooling results in melting or other fuel displacement, it is unlikely that a critical mass in a new form will result. The actual amount of fuel may vary from as little as about one pound to tens of thousands of pounds depending on fuel enrichment, fuel form, reactor type, and many other factors.

2-4 Fire in Control Systems.

2-4.1

The possible effects of heat, smoke, and corrosive gases on the operation of control systems require attention to features of good practice and fire protection so as to minimize interference with operation of these systems. Features of good design include compartmentalization, minimizing combustible materials, and installation of automatic fixed extinguishing systems. The physical separation of alternative systems for control and safe shutdown of the reactor should be considered and provided to the extent practical.

2-4.2

Electrical control mechanisms involve combustible insulation. Hydraulic controls sometimes involve combustible fluids. The control panels may be exposed to fire damage if located near wood platforms or in spaces having combustible building finish or furnishings.

2-4.3

If fire involving a reactor control system causes reactor shutdown, the need for continued cooling of fuel elements will be reduced, but will not, in most cases, be eliminated.

2-5 Loss of Coolant or Moderator.

2-5.1

Another type of possible accident might be the loss of either moderator or coolant in a reactor operated for a time at or near full power. Sufficient residual heat might remain in the reactor fuel elements to melt them. The possibility of this occurrence in research reactors is extremely remote.

2-5.2

The possibility of chemical reaction of core or coolant materials under conditions of equipment failure must be taken into account. Coolant fires may, for example, result from leaks in sodium or organic coolant systems; sodium-water reactions may result from failures in sodium-water heat exchangers, and graphite may burn if air is inadvertently introduced into a very hot graphite core. Core design questions are involved in the choice of core materials, in the prediction of chemical reaction and radiolysis rates in the core, and possibly in the selection of in-core instrumentation for the detection of troublesome chemical situations.

2-6 Hydrogen Explosions.

2-6.1

The intense gamma radiation to which light or heavy water is subjected causes some decomposition into hydrogen and oxygen. Sealed reactors using water for moderator or coolant, or both, are equipped with collecting chambers to prevent the accumulation of hydrogen-oxygen mixtures from occurring in the reactor or accompanying piping.

2-6.2

Usually the hydrogen and oxygen are recombined catalytically. In reactors such as the swimming pool type, the rate of evolution of hydrogen is such that dissipation of the gas through openings present in a normal building, doors, crevices, and the like, will be more than adequate to prevent concentrations of hydrogen within the explosive range.

2-7 Electric Circuits and Wiring.

2-7.1

Electrical circuitry and components in reactor facilities present the same type of fire protection problems as in other industrial facilities. The prime concern in the reactor facility is directed towards those circuits and components essential to continued operation of the reactor and particularly to those essential to a safe shutdown under emergency conditions. For these reasons, special care is devoted to redundancy of systems, emergency power supplies, separation, physical protection, and reliability.

2-7.2

Because of the prime importance of much of the electrical equipment in a reactor facility, it is essential that fire protection measures for electrical equipment be adequate to ensure continuity of operations, at least to the extent of assuring safe shutdown conditions. Protection of cables, separation of redundant circuits, protection of penetrations (particularly through fire-rated partitions), and adequacy of alarm and interlocks is essential. The smoke and toxic products of combustion developed in most electrical fires, together with the smaller number of people available for emergency response (as compared to a manufacturing facility) increase the need for automatic protection systems in critical areas.

2-7.3

Electrical fires in reactor facilities may present greater loss potentials than in other facilities. Due to the stringent quality and reliability requirements for reactor facilities, equipment damaged by smoke and other products of combustion may be replaced when the same equipment in nonnuclear facilities could be salvaged and restored to service. This aspect of the damage potential further justifies additional fire prevention and protection measures in the nuclear facility.

2-8 Incompatible Materials.

Careful design analysis is important to the reduction of the fire protection problems inherent in the use of materials that are incompatible in fire situations. As an example, the use of liquid metal as a reactor coolant may require special extinguishing systems not utilizing water. The possibility of water/liquid metal reactions may justify the exclusion of water systems from the area. When such a condition exists, it may impose more severe limitations on the presence of combustible oils, plastics, insulations, and other materials that generally require water for fire extinguishment. Where such mixed hazards exist, it is important that careful consideration be given to the potentials for a failure in one system to cause a failure in the incompatible system. In such cases, either a protection system should be provided that can insure the extinguishment of fire in either system before it can cause a rupture of the other systems, or a single protection system (such as inerting) should be developed that is adequate for either hazard. The difficulties inherent in such problems warrant the most thorough hazards analysis at the earliest design stages.

Chapter 3 Fire Protection for Nuclear Research and Production Reactor Facilities

3-1 Preplanning.

3-1.1

In planning the construction and operation of facilities of which a nuclear reactor is part, attention should be given to adequate fire and explosion protection. Regulatory bodies and insurance organizations are often a source of practical recommendations. These agencies, including the fire department and other organizations that might be called to a fire, should be consulted at the planning stage to avoid the need for later adoption of protective measures at increased cost and delay.

3-1.2

As in any industrial plant, the fire hazard in nuclear reactor assemblies is generally due to the normal features of combustibility of building construction and contents. However, the fire and explosion problem is complicated by certain factors not present to the same degree in other plants. The behavior of materials at high temperatures and pressures is involved. The factors of radioactivity and contamination introduce a special hazard.

3-1.3

NFPA 801, *Recommended Fire Protection Practice for Facilities Handling Radioactive Materials*, applies specifically to all such facilities except nuclear reactors. However, the provisions of that publication are applicable to the fire protection needs in reactor facilities.

3-2 Fire Problems.

3-2.1

All facilities handling radioactive materials should be designed and operated in accordance with the usual good practices, but with special recognition given to the unique properties of radioactive materials. The effects of the presence of radioactive substances upon the extent of loss caused by fire, explosion, or other perils are:

(a) Possible interference with manual fire fighting due to the real or imagined fear of exposure of fire fighters to radiation.

(b) Possible increased delay in salvage work and in resumption of normal operations following fire, explosion, or other damage due to radioactive contamination and the consequent need for decontamination of buildings, equipment, and materials.

(c) Possible increase in the total damage resulting from contamination of buildings and equipment.

3-2.2

It is possible that radioactive materials may melt, vaporize, oxidize, and become airborne under fire conditions. None of these physical or chemical changes will slow or halt the radioactivity. It is conceivable that certain radioactive materials under fire conditions might be converted to radioactive vapor or oxidized to a radioactive dust or smoke. This dust or smoke could be carried by air currents and subsequently deposited on other parts of the involved buildings or even on neighboring buildings or land. These loss- and personal injury-aggravating characteristics of radioactive materials justify a higher-than-normal degree of protection against fire and explosion at those facilities where this potential exists. The use of fire-resistive building components and equipment is highly desirable in those areas where radioactive materials are to be located or used. Automatic extinguishing systems are highly advantageous wherever combustibles are encountered, since this makes it less necessary for personnel to expose themselves to possible danger. These systems automatically begin the fire control process, sound an alarm, and make efficient use of the extinguishing agent available. (*See Section 2-8, Incompatible Materials, for possible exceptions.*)

3-3 Plant Organization for Fire Protection.

3-3.1

A fire prevention and protection organization should be established as an integrated department of plant management and provided sufficient responsibility, authority, and manpower to permit effective performance on a 24-hour-a-day basis.

3-3.2

In a well-organized reactor facility, fire control planning starts well before the fire occurs. The need for prefire planning for such facilities cannot be overemphasized. A statement of policy by the management of the facility as to the intent of the plan, its scope, its importance, and its organization will materially assist in its effective application. It should be published, reviewed at periodic intervals, kept current, and properly implemented.

3-3.3

The areas of consideration of facility management in designing their preplanning for an emergency program should include as a minimum the following:

(a) A self-inspecting program.

(b) An emergency and fire fighting organization with an outline for its training operation.

(c) Personnel control as it relates to emergency situations.

(d) Health physics group responsibilities.

(e) A coordinated response plan with public emergency forces, including periodic drills.

(f) Procedures for loss-minimization and decontamination.

(g) The safeguarding of valuable process data and records.

(h) Community relations.

3-4 Self-Inspection Program.

The self-inspection program should be formal and conducted objectively by knowledgeable employees who have a good understanding of the hazards to be safeguarded.

3-4.1

The reports of these inspections should be reviewed by management at a level that can initiate corrective action. The self-inspection report forms should be specifically designed for each facility and include all aspects of basic fire protection as well as those unique to the facility.

3-5 Planning for Handling Emergencies.

3-5.1

In a plant involving a nuclear reactor, the problems affecting decisions on how best to deal with a fire or other emergency are not those that can be solved by simply calling the public fire department. As many decisions as possible should be made with respect to the types of fire or emergency to be expected, and these decisions should be made in advance.

3-5.2

The emergency procedures should be thoroughly practiced if they are to be successful. The problem of fire fighting does not lend itself to haphazard attack. The particular fire fighting measures to be taken may involve shutting down or isolating parts of the plant or individual items of equipment. As far as possible, procedures should be developed for handling such situations.

3-5.3

In general, the plant fire brigade should be in immediate charge of a fire area or an area of damage, but the exact operations that it may perform should be those largely decided upon in advance.

3-5.4

In most plants involving a reactor there will be many parts of the property where fire fighting does not involve any abnormal situations. The places where special procedures are necessary should be identified and the procedures for the special areas thoroughly understood.

3-5.5

Arrangements should be made for the prompt calling of the public fire department through reliable recognized means. However, the plant fire protection department should plan in advance with the public fire departments the operations of fire fighters coming into the plant in order that their activities will be properly coordinated with the plant’s program for dealing with emergencies.

3-5.6

The plant manager in charge at the time of the emergency should know under what conditions the public fire forces may operate in the plant. This is necessary so the exposure of fire fighters to unnecessary danger may be avoided and the plant’s operations may not be unreasonably interrupted by emergency measures undertaken with good intent, but without a proper understanding of their consequences.

3-5.7

Where fire fighters may be called upon to deal with a situation involving radioactivity, the plant should provide the necessary instruments and personnel for evaluating the degree of hazard. For fire fighting or emergency operations in areas where fire fighters, including public mutual aid departments, might be exposed to radioactivity, the workers permitted in these areas should be fully trained and provided with suitable protective clothing, respiratory protective equipment of a suitable type, and instruments for recording radiation exposure for each individual.

3-5.8

The emergency planning should cover measures to prevent the spread of contamination and for effective and prompt decontamination in the event of accidental release of radioactive materials. Operations offices of the U.S. Nuclear Regulatory Commission can provide assistance in certain emergencies.

3-6 Location and Construction.

3-6.1

Site-selection studies should include a review of exposures from fire and explosion. Accessibility (e.g., in abnormal weather), floods, lightning-prone terrain, air traffic, seismicity, and tornado belts should be among the geographical, geological, and meteorological features requiring consideration for site selection. Deficiencies should require compensatory action from a protection point of view. Lightning protection should be in accordance with NFPA 780, *Lightning Protection Code*.

3-6.2

A good construction fire safety program should insure that all penetrations of a containment vessel, if provided, should be suitable for evacuation and remain open during the construction period. (*See NFPA 241, Standard for Safeguarding Construction, Alteration, and Demolition Operations.*)

3-6.3

Installation of utilities and equipment in the containment vessel requires special care to maintain a low level of combustibles.

Since reactor equipment must meet very high levels of quality assurance, reactor equipment that has been subjected to fire and smoke damage is much more likely to require replacement than similarly exposed equipment in normal industrial installations. Special efforts are warranted to reduce the usual accumulation of packing cases, cartons, insulation, and other combustibles to an acceptable level. This may take the form of conducting all uncrating operations outside the containment vessel and providing special handling devices to transport unpackaged items into the vessel.

3-6.4

The difficulties of access and visibility, if a fire occurs where a containment vessel is provided, warrant the provision of temporary fixed automatic extinguishing systems when combustibles cannot be effectively controlled. Temporary interior hose stations and an ample supply of portable extinguishing equipment should be provided within easy reach of all portions of the vessel. Because of the smoke confinement potential, only very fast manual response may be effective and manual fire fighting equipment should be provided in quantities considerably in excess of normal construction practice to insure the earliest response.

3-6.5

The site of a nuclear reactor should have an adequate and highly reliable water supply system. It should be designed to provide water for fire protection and also to provide water for various normal and emergency requirements. Site facilities for disposal or retention of water that may be contaminated should also include sufficient capacity to handle runoff during fire fighting. Buildings protected by automatic extinguishing systems will generally require less retention capacity than facilities that are dependent upon manual fire fighting efforts.

3-6.6

Features of building construction that would introduce fire or explosion complications should be avoided. All construction should be noncombustible to avoid complications of fire hazard. For example, where all finish materials are used for decorative, acoustical, or insulation purposes, they should be noncombustible and of types to make decontamination more easily accomplished.

3-6.7

The exposure of the reactor to other buildings should be minimized by such means as spatial separation or by suitable barriers with provision for entry and egress.

3-6.8

The design and arrangement of the facility should be such as to provide adequate fire exits for people working in any of the areas of the facility. NFPA *101*,® *Life Safety Code*,® can serve as a guide.

3-7 Ventilation.

3-7.1

The designer should also consider fire and smoke spread within the building in the design of ventilation systems.

3-7.2

Air duct systems in a space or building may act as flues for heat or smoke, permitting fire and radioactive contaminants to spread. Large ducts and shafts are spaces in which the installation of automatic extinguishing systems and/or dampers may be needed. Ducts should be noncombustible and installed in accordance with NFPA 90A, *Standard for the Installation of Air Conditioning and Ventilating Systems*. Filters should be of the UL Class 1 Type. High efficiency particulate air filters should conform to UL Standard 586 and Military Specification MIL-F-51068C; combustible filters should not be used.

3-8 Electrical Equipment.

3-8.1

Electrical equipment should be installed in accordance with NFPA 70, *National Electrical Code*.® Special consideration should be given to methods whereby radioactive contaminating substances carried by smoke or fumes may be prevented from entering electrical conduit ducts and fittings. Openings into devices or equipment should be sealed to prevent the entrance of contaminants.

3-8.2

Wiring ducts through walls, floors, and ceilings introduce an opportunity for the spread of fire or contaminated liquid or gas from one space to another. Fire stops in and around ducts should separate one space from another.

3-8.3

Electrical control equipment, wiring, or other electrical facilities that are important to the operation and safe shutdown of a reactor plant should be protected by automatic extinguishing systems and fire barriers. The degree of protection needed should be determined by an analysis of the fire exposure from the jacketing and insulation of the extensive wiring network and from combustible materials within or near the equipment. Extreme care in the layout and selection of materials and components, to minimize the fire loading and fire exposures to critical components, is needed during the design phase.

3-8.4

Emergency power supplies should be provided for essential control systems. Transfer to emergency supply should be done automatically upon interruption of the main power source. Emergency power supplies may consist of an automatically started, motor-generator set, an alternate feeder from the power generating station, or a set of batteries maintained under constant charge.

3-8.5

Controls should be of fail-safe design so that loss of control systems will not produce a hazardous condition, such as loss of reactor control. Where this is not possible or control is necessary under conditions of adversity, duplicate control circuitry should be provided.

3-8.6

Circuits and equipment depended on for primary safety should be electrically supervised; that is, the circuits arranged so that they carry current under normal conditions, with relays arranged to drop out and produce audible or visible signals if the circuits are accidentally broken. In the case of circuits and equipment intended to monitor special services such as air supply, liquid level in tanks and so forth, where this information is important to the safety of the installation, the supervised circuit and equipment should be arranged so that a break or a ground in a conductor on the circuit will result in a trouble signal rather than an alarm signal. Where extreme reliability is needed, the circuit should be arranged to produce the alarm signal even if a broken wire or a ground accidentally occurs. Under these conditions, the arrangement of circuit and parts should be such that an audible signal cannot be silenced without a corresponding visual signal.

3-9 Flammable Liquids and Gases.

3-9.1

The use of nonflammable cleaning solvents is strongly encouraged. Flammable liquids, except for amounts required for actual operations, should be stored in accordance with NFPA 30, *Flammable and Combustible Liquids Code*. The use of even small quantities of flammable liquids in safety cans should be permitted in and about the reactor assembly only with specific permission from the plant fire protection manager.

3-9.2

Flammable liquids or gases that may of necessity be piped into the nuclear reactor areas should have outside emergency shutoffs. Piping, valves, and safety devices should be in accordance with NFPA 30, *Flammable and Combustible Liquids Code*, and NFPA 54, *National Fuel Gas Code*.

3-9.3

Compressed flammable gas cylinders should be stored outside the reactor area in a ventilated cutoff room or outdoors, to be brought in only for purposes specifically authorized.

3-10 Ordinary Combustibles.

3-10.1

Combustibles associated with reactors are not limited to those having characteristics requiring special protective measures. The quantity of ordinary combustibles, such as wood and paper, is frequently the most serious factor in fire exposure.

3-10.2

Combustible materials, whether for shielding, for experiments or research, for maintenance, or for any use unrelated to reactor operation, should not be allowed to expose the reactor or critical components. Operations requiring the use of combustibles should be in other appropriate adequately protected areas.

3-11 Extinguishing Systems.

3-11.1

Both operation of the reactor and emergency shutdown depend on control mechanisms and equipment that should be designed so that a fire will not prevent their vital operations. Therefore, continuity of operation of critical control equipment may dictate the use of extinguishing agents other than water. Systems employing carbon dioxide, halogenated hydrocarbons, dry chemical, and foam may be required. Physical and chemical compatibility of the extinguishing agent to the hazard to be protected should be considered in system selection. These systems should be designed and installed in accordance with the applicable NFPA standard. Guidance may be found in NFPA 11, *Standard for Low Expansion Foam and Combined Agent Systems*; NFPA 11A, *Standard for Medium- and High-Expansion Foam Systems*; NFPA 12, *Standard on Carbon Dioxide Extinguishing Systems*; NFPA 12A, *Standard on Halon 1301 Fire Extinguishing Systems*; NFPA 12B, *Standard on Halon 1211 Extinguishing Systems*; NFPA 13, *Standard for the Installation of Sprinkler Systems*; NFPA 15, *Standard for Water Spray Fixed Systems for Fire Protection*; NFPA 16, *Standard on Deluge Foam-Water Sprinkler and Foam-Water Spray Systems*; NFPA 16A, *Recommended Practice for the Installation of Closed-Head Foam-Water Sprinkler Systems*; and NFPA 17, *Standard for Dry Chemical Extinguishing Systems*.

3-11.2

Automatic sprinkler systems or specially designed automatic fixed water spray systems should be the first consideration for fire protection in those locations where fire possibilities exist. Such systems can operate with full effectiveness under conditions of radiation or contamination that would make approach by fire fighters impossible. Water is usually preferable over other extinguishing media where there is need for retention and control of radioactive contaminants.

3-11.3

The collection and disposal of water used in fire fighting may be an important factor in limiting the extent of the reactor assembly or the areas of associated buildings affected by radioactive contamination. This consideration alone suggests that, for many of the building spaces, a well-designed sprinkler system is preferable to dependence on manual fire fighting. It is better to pipe water for fire fighting into spaces where a fire might have to be fought through a system of automatic sprinklers or a system specially designed for the purpose, rather than have to combat a fire by directing hose lines into a smoke-obscured space and distributing the water in a less efficient manner.

3-11.4

In spaces where water used in fire fighting would be subject to possible contamination, the collection and disposition of water so used should be provided for in the facilities of the reactor plant. This usually means waterproofed floors and controlled floor drainage. Substantial capacity of such drainage systems would be required if hose streams and manual fire fighting is necessary. With sprinklers, or specially designed systems, relatively smaller amounts of water may have to be disposed of. Also, “on-off” sprinklers and flow cycle valves may be considered to further minimize water discharge.

3-11.5

The relative importance of ventilation to release heat, smoke, and hazardous gases developed in a fire is mitigated to some degree by automatic sprinklers or by a specially designed protection system. Such systems tend to reduce three-dimensional problems to more manageable two-dimensional ones.

3-12 Standpipe and Hose System.

A network of inside hose connections should be provided throughout the facility. Spacing and installation should conform to NFPA 14, *Standard for the Installation of Standpipe and Hose Systems*. Nozzles should be adjustable spray/straight stream type. In the vicinity of electrical equipment, nozzles approved for Class C areas should be used.

3-13 Portable Fire Extinguishers.

3-13.1

For first-aid fire protection, suitable fire extinguishers should be installed in accordance with NFPA 10, *Standard for Portable Fire Extinguishers*.

All employees who may at any time be expected to operate a fire extinguisher or hand hose should receive training and be assigned to first-aid fire fighting duty in accordance with a carefully worked out plan for each department of their plant.

3-13.2

Incipient fires may be controlled by portable fire extinguishers. This phase of fire control is particularly important, even though automatic extinguishing systems and hand hose connections have been provided. A supply of portable hand fire extinguishers suitable for use on the specific hazards encountered should be provided (*see NFPA 10, Standard for Portable Fire Extinguishers*).

3-13.3

Special fire potentials sometimes encountered involve unusual chemicals or combustible metals. Some special extinguishers are effective on incipient fires in combustible metals. Dry powder extinguishers, approved for combustible metal fires, are effective on most such materials (*see NFPA 480, Standard for the Storage, Handling and Processing of Magnesium; NFPA 481, Standard for the Production, Processing, Handling, and Storage of Titanium; and NFPA 482, Standard for the Production, Processing, Handling, and Storage of Zirconium*).

3-13.4

Some extinguishing agents may have undesirable effects on personnel and some types of equipment. It is important that this possibility be evaluated.

3-14 Fire Detection.

3-14.1

It should be recognized that fire detection in itself does not extinguish the fire and is only as good as the follow-up action to be provided.

3-14.2

The need for and the type of detection services should be related to the hazard, the extinguishing systems, public and private fire departments, or combinations of these.

3-14.3

Various devices are available that operate on different principles for detecting fire. These include, but are not limited to, the principles of fixed temperature, rate-of-temperature-rise, presence of combustible products, IR or UV flame sensing, or a combination of some of these principles.

3-14.4

A properly engineered fire detection system in accordance with NFPA 72 and NFPA 72E can be used to: (1) alert the building occupants of a fire condition so they can evacuate the premises, (2) summon organized assistance to undertake, or assist in, fighting the fire, (3) shut down equipment or processes that may contribute to the consequences of a fire, and (4) actuate fire control equipment.

3-14.5

If no private fire control organization is available and the public protection forces are inadequate or distant, a good detection system will serve to alert personnel to evacuate the building.

3-15 Fire Hazard Analysis.

3-15.1

A thorough fire hazard analysis is necessary to incorporate adequate fire protection into the facility design. Integrated design of systems is necessary to insure the safety of the facility and the operators from the hazards of fire and to insure that fire cannot prevent the safe shutdown of the reactor under emergency conditions.

3-15.2

The following steps are recommended as part of the analysis procedure.

3-15.2.1 Prepare a general description of the physical characteristics of the facility that will outline the fire prevention and fire protection systems to be provided. Define the fire hazards that can exist and state the fire risk evaluation to be used in the design of the facility. Describe the design basis fire that will be considered and used in the design of the fire protection system.

3-15.2.2 List the codes and standards that will be used for the design of the fire protection systems. Include the published standards of the National Fire Protection Association. Select the specific sections and paragraphs, not general items.

3-15.2.3 Define and describe the potential fire characteristics for all individual plant areas that have combustible materials, such as: maximum fire loading, hazards of flame spread, smoke generation, toxic contaminants, and fuel contributed. Consider the use and effect of noncombustible and heat-resistant materials.

3-15.2.4 List the fire protection system requirements and the criteria to be used in the basic design for such items as water supply, water distribution systems, and fire pump capacity.

3-15.2.5 Describe the performance requirements for the detection systems, alarm systems, automatic suppression systems, manual systems, chemical systems, and gas systems for fire detection, confinement, control, and extinguishing.

3-15.2.6 Develop the design considerations for suppression systems and for smoke, heat, and flame control, combustible and explosive gas control, toxic and contaminate control. Select the operating functions of the ventilating and exhaust systems during the period of fire extinguishing and control. List the performance requirements for the fire and trouble annunciator warning system.

3-15.2.7 In the review and selection of the appraisal and trend evaluation systems that may be provided with the alarm detection system in the fire protection system, consider the qualifications required for the personnel performing the inspection checks and the frequency of testing to maintain a reliable alarm detection system.

3-15.2.8 The features of the facility generally define the methods for fire prevention, fire extinguishing, fire control, and control of hazards created by fire. Fire barriers, egress, fire walls, and the isolation and containment features that should be provided for flame, heat, hot gases, smoke, and other contaminants should be carefully planned. Outline the drawings and list of equipment and devices that are needed to define the principal and auxiliary fire protection systems.

3-15.2.9 Prepare a list of the dangerous and hazardous combustibles and the maximum amounts estimated to be present in the facility. Evaluate where these will be located in the facility.

3-15.2.10 Review the types of maximum credible fires, based on the quantities of combustible materials, their estimated severity, intensity, duration, and the hazards created. Indicate for each of the types reviewed the total time involved and the time for each step from the first alert of the fire hazard until safe control, extinguishment, or safe shutdown of the facility is accomplished. Describe in detail the plant systems, functions, and controls that will be provided and maintained during the fire emergency.

3-15.2.11 Define the essential electric circuit integrity needed during the fire. Evaluate the fire confinement control and extinguishing systems that will be required to maintain their integrity.

3-15.2.12 Analyze what is available in the form of backup or public fire protection to be considered for the installation. Review the backup fire department, equipment, manpower, special skills, and training required.

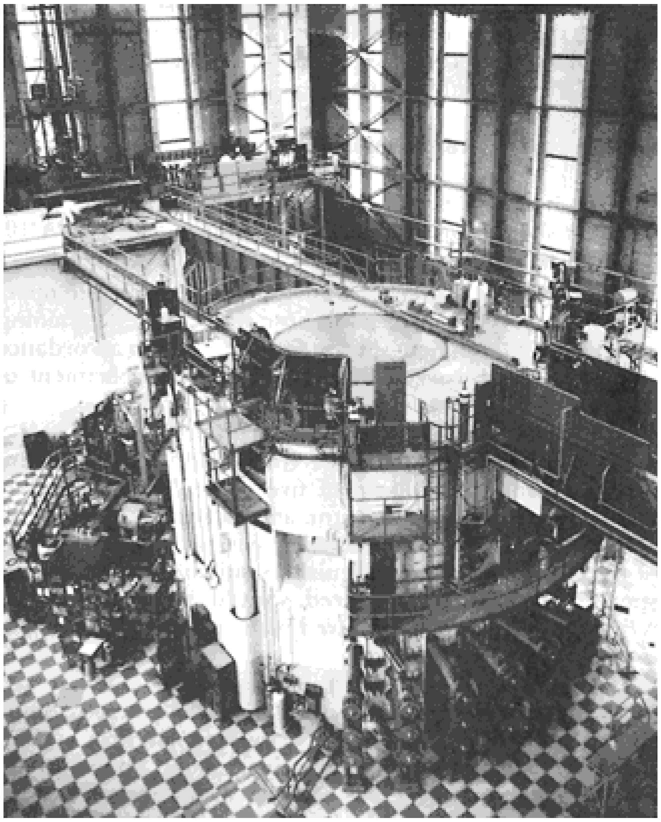
3-15.2.13 List and describe the installation, testing, and inspection required during construction of the fire protection systems that demonstrate the integrity of the systems as installed. Evaluate the operational checks, inspection, and servicing required to maintain this integrity.

3-15.2.14 Review the qualification requirements for the fire protection engineer or consultant who will assist in the design and selection of equipment. This person will also inspect and test the complete physical aspects of the system and develop the complete fire protection program for the operating plant.

Chapter 4 Problems of Specific Research and Production Reactor Types

4-1 General.

The principal fire hazards are likely to be due to the peculiar circumstances existing in any occupancy in which research is being carried on. With a number of research projects calling for the use of numerous experimental facilities, the normal condition is to find much experimental apparatus set up. This provides a degree of congestion that involves potential fire hazards to both material and personnel. The use of combustible materials should be very strictly limited. (*See Figure 4-1.*)



(*Courtesy Atomic Energy of Canada, Ltd.*)

Figure 4-1 This illustration shows what the working space around a research reactor may look like. The congestion of valuable instruments and apparatus explains why it is necessary to strictly limit combustible material. This is the Canadian NRX heavywater moderated reactor. It has heavy shielding including a heavy cover.

4-1.1

Combustible acoustic or other wall finishes introduce unnecessary fire hazards. Furniture should be noncombustible.

4-2 Fire Protection.

The principal fire protection needed is to deal with a congested accumulation of combustible material. Even with the best supervision, there is likely to be enough combustible material to seriously damage experimental apparatus in case of fire. Fire, smoke, and the fire fighting operations could spread contamination throughout the building.

4-2.1

General protective measures should include portable extinguishers and automatic fixed extinguishing systems for the working space around the reactor and application of the principles of containment in the design and arrangement of the building.

4-2.2

Normal use of these reactors is at power levels where ordinary convection and thermal radiation will dissipate heat produced at the core. Some do require additional cooling, usually by water.

4-2.3

The collection and disposal of water used in fire fighting may be extremely important in preventing the spread of contamination. For this reason a well-designed fire protection system is preferable to manual fire fighting. If sprinklers and floor drains are properly arranged, water used in fixed systems can be better controlled than if the water must be employed through hose lines.

4-3 Access and Ventilation.

The design of the working space around the reactor should be such that controlled ventilation of smoke from small fires is possible. In connection with this, the exposure hazard due to smoke being radioactive must be considered. It is not likely that this radioactivity would be from fission products, but from induced radiation in experiments.

4-3.1

Working space around the reactors should, as a matter of common practice, provide at least two avenues of escape for personnel, and these exits should be arranged as remote, one from the other, as possible. These avenues are also necessary to provide access for manual fire fighting operations as necessary.

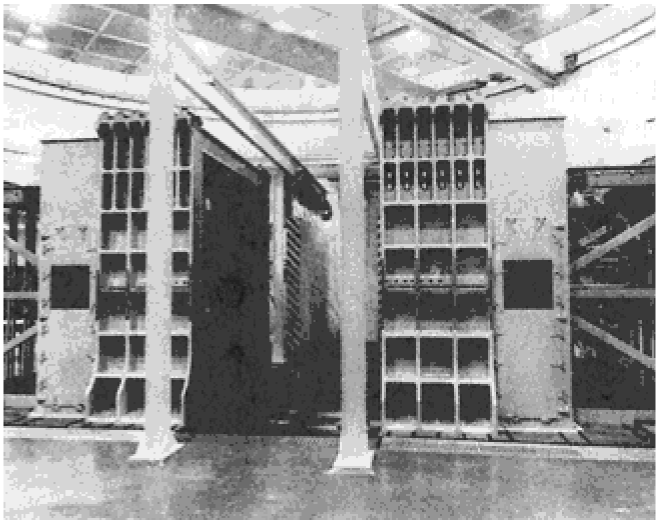
4-4 Site Factor.

While research reactors could, under conditions of poor building design, introduce some exposure hazard, their fire exposure hazard on the whole is low, and the radioactive contamination potential does not appear to be excessive.

4-5 Critical Experiment.

4-5.1 Field of Use.

The critical experiment involves the components of a reactor without the assembly necessarily being as complete as would be a final design. It is strictly for experimental purposes. (*See Figure 4-5.1.*)



(*Credit: Argonne National Laboratory, Idaho Div.*)

Figure 4-5.1 National Reactor Testing Station, Idaho. Pictured is the Zero Power Plutonium Reactor (ZPPR) assembly machine located in the reactor cell of the facility. The ZPPR facility is in support of the Fast Breeder Reactor Program. The reactor is shown with the two halves separated and the personnel shields and loading platform retraced. The matrix face [10 ft (3.05 m) by 10 ft (3.05 m)] of the stationary half can be seen at the left center of the photograph. Rod drives with their support frames are also mounted at the back of each half of the reactor.

4-5.1.1 The critical experiment is assembled for the purpose of learning from actual operation many of the characteristics of the reactor system under study. These include (1) verification of the calculated value of critical mass, (2) an approximation, by neutron flux measurement, of the distribution of power within the core, (3) indication of the temperature coefficient of reactivity, (4) effects and calibration of control devices, and (5) studies of the behavior of different materials used in the core.

4-5.1.2 Critical experiments can be made entirely for obtaining technical information and data without any specific type of reactor being represented.

4-5.2 Description.

The construction of the critical facility is such as to allow differences in the kinds, amounts and arrangement of core, moderator, and reflector components.

4-5.2.1 The general arrangement of the parts resembles the type of the reactor under study, but because of the low power generation, pressurizing of high-pressure water designs may not be necessary, shielding may be reduced, and the overall construction greatly simplified. Low power generation eliminates the heat transfer apparatus necessary to cool the reactor.

4-5.2.2 The critical experiment does not produce a significant quantity of highly radioactive fission products as a power reactor does. Thus, after operation, the reactor can usually be disassembled and the parts studied without extensive protection against radiation.

4-5.3 Fuel.

In these experiments the fuel might be any of the materials suitable for the purpose ranging from completely noncombustible to the involvement of pyrophoric materials.

4-5.4 Controls.

The critical assembly usually is initially equipped with standard control actuators. As an assembly approaches the final design, parts of a control system of new design may be introduced to check operating characteristics.

4-5.4.1 Extra controls, safety devices, and "scram" provisions are usually used in experimental work, since there may be errors or inaccuracies in calculated characteristics. Some of these extra safety measures may include safety rods, means for quickly dumping liquid moderators or reflectors, or arrangements for withdrawing sections of the core or solid moderators or reflectors. Provisions for injecting a neutron-absorbing material or "nuclear poison" such as a boron-containing liquid compound or metal are sometimes used.

4-5.5 Criticality.

A critical experiment is a reactor operating up to and at times slightly above the critical state. Even if the amount of fissionable material in excess of the critical amount in a critical assembly is small, it is possible to produce a nuclear excursion that might result in a power level such that the heat cannot be removed fast enough to prevent a melt-down of fuel components. Radioactive contamination of the experiment room may result, requiring extensive decontamination operations. It is possible, but not probable, that such an accident might rupture the walls or roof of the room, releasing activity to the balance of the building or the outside atmosphere.

4-5.6 Hazards.

The fact that the critical experiment is a research operation may mean that a variety of materials and apparatus will be brought into the working spaces. Hazards associated with the combustibility, flammability, and explosiveness of these, and their reactivity with air, water, and chemicals, should be kept in mind in evaluating the hazard in and near the buildings where the reactor experiments are going on.

4-5.6.1 The use of combustible materials should be eliminated wherever possible, and combustible types of thermal insulation should be completely avoided. Where electrical cables, cords, or wires appear in great numbers, their electrical insulation should be of fire resistant types. Combustible acoustic or other combustible wall finishes introduce unnecessary fire hazards in such an occupancy. Experimental apparatus should be installed on noncombustible boards. Furniture of all sorts should be strictly limited and of noncombustible types.

4-5.6.2 The production of fuel elements should not be in the same area as the reactor. Fuel elements should be stored with care to prevent possible assembly of a critical mass.

4-5.7 Fire Protection.

Automatic extinguishing systems should be installed throughout with special consideration given to other extinguishing media when automatic sprinklers may be unsuitable.

4-5.7.1 As in other reactor plants, the control of water from hose streams is likely to be more difficult than the control of water used in fire fighting from automatic sprinklers or specially designed systems. In every case, the design should involve means for collection of water runoff from fire fighting operations in such a way as to prevent the spread of contamination or the accidental build-up of a critical mass.

4-5.7.2 The exact form of organization for fire protection will depend on circumstances. The critical experiment may be carried on at a location that has an adequate organization responsible for fire protection matters. If not, an organization for fire protection is a necessary part of the management of the critical experiment. The kind of work being done in connection with a critical experiment does not permit leaving decisions with respect to fire fighting matters in the hands of a custodial force. It may be necessary for the building in which the experiment is being carried on to be constantly under the supervision of some person technically competent to handle the overall use of the reactor and its building.

4-5.7.3 In addition, the custodial force should be fully instructed in fire fighting and ventilating procedures, and arrangements must be made in advance so that, if members of a public fire department are likely to respond to a fire call, there will be some responsible administrative officer or custodian who will know under what arrangements the public fire force may go to work. Such arrangements should be worked out between the administration of the reactor property and the chief officer of the city or fire district.

4-5.8 Access and Ventilation.

Radiation shielding will be employed although critical experiments are carried on at near-zero power output. This shielding may be temporary walls or partitions, or it may involve a fixed arrangement of spaces to separate those in which there is radioactivity from those in which there is not. The design of the working space around the reactor should be such that the ventilation of smoke from small fires is possible. The exposure hazard due to radioactive smoke should be considered. Regularly occupied working spaces should provide at least two avenues of escape for personnel, and these exits should be arranged as remote one from the other as possible. The objective should be not only providing exits but also providing means by which access is possible for the operations to control a fire emergency.

In certain experimentation, airborne contamination may be a problem. Where this is the case, the design of the system used for ordinary air conditioning or ventilation should be arranged to cope with such potential contamination.

4-5.9 Site Factors.

The critical experiment may involve a very wide range of hazards to other properties depending upon the nature of the experiment. Consideration of the fundamental dangers of explosion and contamination should be considered in locating the reactor. If adequate water is not available for fire protection as well as for the experiment, additional water for fire fighting purposes should be stored at the site.

4-6 Open Pool Reactor (Swimming Pool Reactor).

4-6.1 Field of Use.

The open pool (swimming pool) reactor is useful for research purposes and is considered versatile, economical, and relatively safe. The shielding that can be provided by the water moderator, and the visibility afforded by its transparency are operating advantages.

4-6.2 Description.

The reactor itself is basically an open top tank filled with purified water. The water in the tank serves as coolant, moderator, reflector, and shield. One pool of this type is concrete, 40 ft long, 20 ft wide, and 20 ft deep (12.2 m long, 6.1 m wide, and 6.1 m deep). Some reactors have a considerable number of ports (beam holes) in the wall so that various experimental apparatus may be set up for the use of the radiation produced (*see Figure 4-6.2*). The building housing the reactor and the working space around it would ordinarily have a tight wall and roof of metal or concrete.

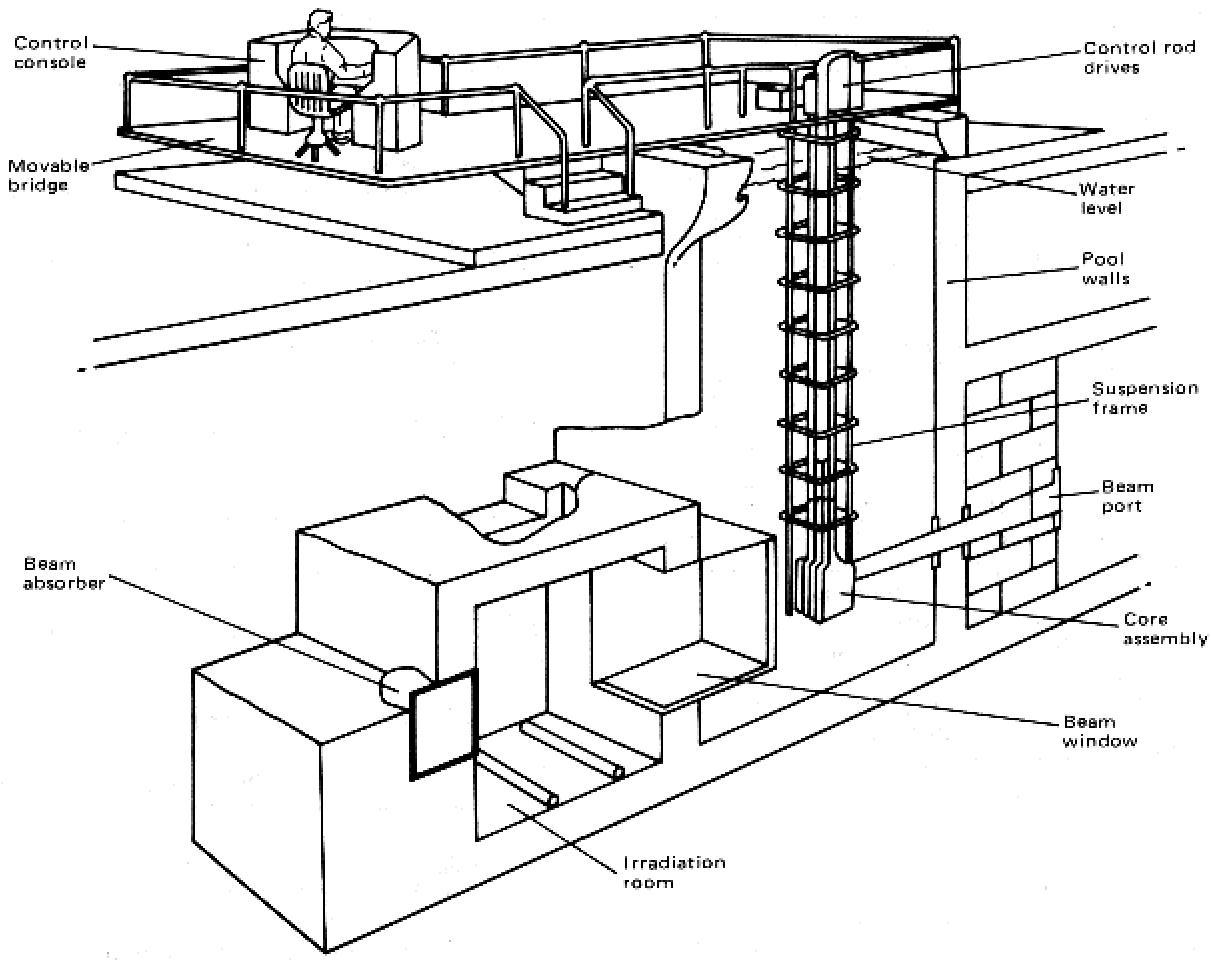


Figure 4-6.2 Open pool (swimming pool) reactor assembly.

4-6.3 Fuel.

The fuel is usually highly enriched uranium in rods or plates. A typical element consists of aluminum-clad plates grouped into fuel assemblies usually about 24 in. by 3 in. by 3 in. (610 mm by 76 mm by 76 mm). (Enriched uranium simply means that the percentage of U-235 is higher than in natural uranium. The higher the enrichment the smaller the fuel core can be.) A cluster of rods or plates is arranged in a core suspended by a cage in the water from a movable bridge across the top of the pool.

4-6.4 Controls.

Control of the rate at which neutrons are produced is provided by inserting boron or cadmium rods in the proper geometrical pattern between the fuel elements to absorb neutrons. Usually two or three rods are used as control rods and one or two are safety shutdown rods in combination with from 15 to 30 fuel elements. The movement of control rods and fuel elements is accomplished by control mechanisms electrically or hydraulically operated. These are so arranged that, in case of electric or hydraulic failure, the control rods will return by gravity to a position that will shut down the reactor.

4-6.5 Criticality.

In this type of reactor, a critical mass can be reached with about 6 lb (2.7 kg) of 90 percent enriched uranium fuel in a pool of the dimensions described. With lesser degrees of enrichment, more fuel would be required.

4-6.6 Hazards.

This being a water-moderated reactor, hydrogen and oxygen are produced in small amounts by the action of radiation. Provision must be made for safe disposal of this by ventilation.

4-6.6.1 Certain reactor or reactor fuel materials may be subject to chemical action between themselves or such materials as the water moderator, especially at the high temperatures that may be produced accidentally. Obvious hazards are those in the electrical control equipment. Accidents to the electrical equipment should not result in a hazard in the reactor. Because these reactors are used for research many varieties of chemicals may be brought into the working area around the reactor by various experimental setups (*see Figure 4-6.2*). Hazards associated with the combustibility, flammability, and explosiveness of these chemicals and their reactivity with air, water, and other chemicals should be kept in mind in evaluating the hazard in the reactor building at any given time.

4-6.6.2 Defects in fuel element cladding may permit leakage of some radioactive products into the water of the pool.

4-6.6.3 Combustible acoustic or other wall finishes introduce unnecessary fire hazards. Furniture should be noncombustible.

4-6.6.4 General protective measures should include portable extinguishers and automatic extinguishing systems.

4-6.6.5 Normal use of this type of reactor is at power levels where ordinary convection will dissipate heat produced at the core. Heat could be produced rapidly enough to release steam at the pool surface in the event of failure or slow operation of controls. Violent boiling may spread contamination outside of the reactor pool. This might prevent the use of the reactor for an extended period of time and present a decontamination problem. The worst conceivable (but highly improbable) disturbance might produce steam violent enough to cause local structural damage, blow off any apparatus at the top of the pool and probably damage the building.

4-6.7 Site Factors.

While this type of reactor could, under conditions of poor building design, introduce some exposure hazard, its fire exposure hazard, on the whole, is low, and the radioactive contamination hazard does not appear to be excessive. Because of the reactor’s requirement for water, it would likely be located in a place where a satisfactory water supply for fire fighting could be provided.

4-6.8 Organization for Fire Protection.

There should be a fire protection organization. The use of a research reactor means that teams of scientists from a number of separate agencies (several departments of a university, for example) are likely to be occupying the premises at any given time. Each may be performing experiments that introduce some fire hazard condition.

4-6.8.1 The agency responsible for the operation of the reactor or plant should consider having on duty during all working times persons technically competent to handle the overall use and operation of the reactor and the building. Whether the reactor and the building may safely be left in the hands of a custodian at times when it is not used, such as nights, weekends, or holidays, should be considered. In addition, the custodial force should be fully instructed in fire fighting and ventilation procedures, and arrangements should be made in advance so that, if members of a public fire department are likely to respond to a fire call, there will be some responsible administrative officer or custodian who will know under what arrangements the public fire force may go to work. Such arrangements should be worked out between the administration of the reactor property and the officials of the city or fire district.

Chapter 5 Referenced Publications

5-1

The following documents or portions thereof are referenced within this recommended practice and should be considered part of the recommendations of this document. The edition indicated for each reference is the current edition as of the date of the NFPA issuance of this document.

5-1.1 NFPA Publications.

National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.

NFPA 10, *Standard for Portable Fire Extinguishers*, 1990 edition

NFPA 11, *Standard for Low Expansion Foam and Combined Agent Systems*, 1988 edition

NFPA 11A, *Standard for Medium- and High-Expansion Foam Systems*, 1988 edition

NFPA 12, *Standard on Carbon Dioxide Extinguishing Systems*, 1993 edition

NFPA 12A, *Standard on Halon 1301 Fire Extinguishing Systems*, 1992 edition

NFPA 12B, *Standard on Halon 1211 Fire Extinguishing Systems*, 1990 edition

NFPA 13, *Standard for the Installation of Sprinkler Systems*, 1991 edition

NFPA 14, *Standard for the Installation of Standpipe and Hose Systems*, 1993 edition

NFPA 15, *Standard for Water Spray Fixed Systems for Fire Protection*, 1990 edition

NFPA 16, *Standard for the Installation of Foam-Water Sprinkler Systems and Foam-Water Spray Systems*, 1991 edition

NFPA 16A, *Recommended Practice for the Installation of Closed-Head Foam-Water Sprinkler Systems*, 1988 edition

NFPA 17, *Standard for Dry Chemical Extinguishing Systems*, 1990 edition

NFPA 30, *Flammable and Combustible Liquids Code*, 1990 edition

NFPA 54, *National Fuel Gas Code*, 1992 edition

NFPA 70, *National Electrical Code*, 1993 edition

NFPA 72, *Standard for the Installation, Maintenance, and Use of Protective Signaling Systems*, 1990 edition

NFPA 72E, *Standard on Automatic Fire Detectors*, 1990 edition

NFPA 75, *Standard for the Protection of Electronic Computer/Data Processing Equipment*, 1992 edition

NFPA 90A, *Standard for the Installation of Air Conditioning and Ventilating Systems*, 1993 edition

NFPA *101*, *Life Safety Code*, 1991 edition

NFPA 241, *Standard for Safeguarding Construction, Alteration, and Demolition Operations*, 1989 edition

NFPA 480, *Standard for the Storage, Handling, and Processing of Magnesium*, 1987 edition

NFPA 481, *Standard for the Production, Processing, Handling, and Storage of Titanium*, 1987 edition

NFPA 482, *Standard for the Production, Processing, Handling, and Storage of Zirconium*, 1987 edition

NFPA 780, *Lightning Protection Code*, 1992 edition

NFPA 801, *Recommended Fire Protection Practice for Facilities Handling Radioactive Materials*, 1991 edition

NFPA 803, *Standard for Fire Protection for Light Water Nuclear Power Plants*, 1993 edition

5-1.2 Other Publications.

5-1.2.1 NIST Publication. U.S. National Institute for Science and Technology, Gaithersburg, MD 20899.

Handbook 59, *Permissible Dose from External Sources of Ionizing Radiation*, 1954

5-1.2.2 AEC Publications. Nuclear Regulatory Commission, Washington, DC 20555.

Living with Radiation

WASH 1245-1, *Standard for Fire Protection of AEC Electronic Computer/Data Processing Systems*

5-1.2.3 UL Publication. Underwriters Laboratories Inc., 333 Pfingsten Road, Northbrook, IL 60062.

UL 586, *High Efficiency Particulate Air-Filter Units*, 1990

Appendix A A Selection of Additional Reference Material

This Appendix is not part of the recommendations of this NFPA document, but is included for information purposes only.

A-1

The U.S. Department of Energy prepared the following (general interest) publication, which may be ordered from the Department of Energy Technical Information Center, P.O. Box 62, Oak Ridge, TN 37830:

Operational Accidents and Radiation Exposure Experience Within the United States Atomic Energy Commission, 1943-1982, 125 pages, Fall 1971.

A-2

The National Council on Radiation Protection and Measurements has issued a number of reports on specific radiation protection subjects. Price lists are available from NCRP Publications, P.O. Box 4867, Washington, DC 20008, or from the U.S. Government Printing Office. Some applicable publications include:

NCRP 30, *Safe Handling of Radioactive Materials NBS Handbook 92*, 1964

NCRP 38, *Protection Against Neutron Radiation*, 1971

NCRP 39, *Basic Radiation Protection Criteria*, 1971.

A-3

Standards of the U.S. Nuclear Regulatory Commission for protection against radiation are published in the *Code of Federal Regulations* as Part 20, Chapter 1, Title 10, available at most libraries. Revisions are printed in the *Federal Register*, available at subscribing libraries or by subscription from the Government Printing Office.

A-4

A bimonthly magazine, *Nuclear Safety*, is available from the Government Printing Office. It covers many areas of interest, including general safety, accident analysis, operating experiences, and current events.

A-5

Specific requirements for reactor fire protection have been issued by the American Nuclear Insurers, The Exchange, 270 Farmington Ave., Farmington, CT 06032, and the Mutual Atomic Energy Reinsurance Pool, 1151 Boston-Providence Turnpike, Norwood, MA 02062.

NFPA 803

1993 Edition

Standard for Fire Protection for Light Water Nuclear Power Plants

1993 Edition

This edition of NFPA 803, *Standard for Fire Protection for Light Water Nuclear Power Plants*, was prepared by the Technical Committee on Atomic Energy and acted on by the National Fire Protection Association, Inc. at its Fall Meeting held November 16-18, 1992, in Dallas, TX. It was issued by the Standards Council on January 15, 1993, with an effective date of February 12, 1993, and supersedes all previous editions.

The 1993 edition of this document has been approved by the American National Standards Institute.

Changes other than editorial are indicated by a vertical rule in the margin of the pages on which they appear. These lines are included as an aid to the user in identifying changes from the previous edition.

Origin and Development of NFPA 803

The Committee on Atomic Energy was organized in 1953 for the purpose of providing guidance on practices necessary for fire safety in facilities handling radioactive materials. A *Recommended Fire Protection Practice for Nuclear Reactors*, NFPA 802, was developed and officially adopted in 1960. Following a serious fire in 1975 at the Brown's Ferry Plant of the TVA, the Nuclear Regulatory Commission expressed the need for a fire protection standard specifically covering nuclear power plants. The Committee started work on the preparation of this document early in 1976, and their efforts resulted in the first edition being issued in 1978.

Changes in the 1983 edition included a more precise title for the document as well as a complete revision to the chapter on fire alarm systems. The 1988 edition brought the standard into conformance with the NFPA *Manual of Style* as well as making several editorial changes to better explain various sections. This 1993 edition incorporates a variety of changes to the document.

Technical Committee on Atomic Energy

Walter W. Maybee, *Chairman*
Los Alamos Nat'l Laboratories, NM

Wayne D. Holmes, *Secretary*
Professional Loss Control, Inc., PA

Mario A. Antonetti, Gage-Babcock & Assoc. Inc., NY

William G. Boyce, U.S. Department of Energy, DC

Ford W. Burgess, Westinghouse Savannah River Co., SC

Harry M. Corson IV, Cerberus Pyrotronics, NJ
Rep. Nat'l Electrical Mfr Assn.

Donald A. Diehl, Alison Control Inc., NJ

Paul H. Dobson, Factory Mutual Research Corp., MA

Stewart M. Fastman, American Ins. Services Group Inc., NY

James F. Foley, New York Power Authority, NY

Paul Giaccaglia, American Nuclear Insurers, CT

Leonard R. Hathaway, M&M Protection Consultants, IL

LeRoy J. Hill, McDermott Inc., VA

L. S. Homa, Underwriters Laboratories Inc., IL

Donald J. Keigher, Los Alamos, NM

Jacob B. Klevan, Rolf Jensen & Assoc. Inc., VA

Thomas J. Kramer, Schirmer Engineering Corp., IL

Robert S. Levine, Nat'l Inst. of Standards & Technology, DC

Anthony J. Mascena, Stone & Webster Engineering Corp., NJ

J. Edward Maxwell, General Electric Co., CA

David P. Notley, U.S. Nuclear Regulatory Commission, DC

Robert J. O'Laughlin, Knoxville, TN

Mark Henry Salley, Tennessee Valley Authority, TN

Eric J. Shelton, Impell Corp., GA

Clifford R. Sinopoli, Baltimore Gas & Electric, MD
Rep. Electric Light Power Group/Edison Electric Inst.

Rupert M. H. Terrier, Virginia Electric & Power Co., VA

Lynn K. Underwood, Wausau Insurance Cos., WI
Rep. The Alliance of American Insurers

Steven F. Vieira, Grinnell Fire Protection Systems, RI
Rep. Nat'l Fire Sprinkler Assn.

Alternates

Daniel L. Arnold, Rolf Jensen & Assoc., VA
(Alt. to J. B. Klevan)

Ingemar B. Asp, Gage-Babcock & Assoc. Inc., NY
(Alt. to M. A. Antonetti)

James B. Biggins, M&M Protection Consultants, IL
(Alt. to L. R. Hathaway)

L. Paul Herman, Professional Loss Control, Inc., IL
(Alt. to W. D. Holmes)

Jimmy J. Pierce, Tennessee Valley Authority, TN
(Alt. to M. H. Salley)

George Ruetenik, American Nuclear Insurers, CT
(Alt. to P. Giaccaglia)

Gerald R. Schultz, Schirmer Engineering Corp., IL
(Alt. to T. J. Kramer)

Robert W. Strong, General Electric, CA
(Alt. to J. E. Maxwell)

Michael J. Vitacco, Jr., Westinghouse Savannah River Co., SC
(Alt. to F. W. Burgess)

Casey C. Grant, NFPA Staff Liaison

This list represents the membership at the time the Committee was balloted on the text of this edition. Since that time, changes in the membership may have occurred.

NOTE: Membership on a Committee shall not in and of itself constitute an endorsement of the Association or any document developed by the Committee on which the member serves.

Committee Scope: The safeguarding of life and property from fires in which radiation or other effects of nuclear energy might be a factor.

NFPA 803

Standard for
Fire Protection for Light Water Nuclear Power Plants

1993 Edition

NOTICE: An asterisk (*) following the number or letter designating a paragraph indicates explanatory material on that paragraph in Appendix A.
For information on referenced publications see Chapter 18.

Chapter 1 Introduction

1-1* Scope.

This standard covers the protection of light water nuclear power plants from the consequences of fire, including safety to life of on-site personnel, protection of property, and continuity of production. Nuclear safety is provided for in other documents such as Nuclear Regulatory Commission (NRC) regulations.

1-2 Purpose.

This standard is prepared for the use and guidance of those charged with the design, construction, operation, and protection of light water nuclear power plants. This standard covers those requirements essential to assure that the consequences of fire will have minimum impact on the safety of construction and operating personnel, the physical integrity of plant components, and the continuity of plant operations. Additional emphasis is on requirements dictated by the need to protect the lives of constructors and operators from the consequences of fire and to conform to best fire protection engineering practice.

1-3 Definitions.

Approved. Acceptable to the “authority having jurisdiction.”

NOTE: The National Fire Protection Association does not approve, inspect or certify any installations, procedures, equipment, or materials nor does it approve or evaluate testing laboratories. In determining the acceptability of installations or procedures, equipment or materials, the authority having jurisdiction may base acceptance on compliance with NFPA or other appropriate standards. In the absence of such standards, said authority may require evidence of proper installation, procedure or use. The authority having jurisdiction may also refer to the listings or labeling practices of an organization concerned with product evaluations which is in a position to determine compliance with appropriate standards for the current production of listed items.

Authority Having Jurisdiction. The “authority having jurisdiction” is the organization, office or individual responsible for “approving” equipment, an installation or a procedure.

NOTE: The phrase “authority having jurisdiction” is used in NFPA documents in a broad manner since jurisdictions and “approval” agencies vary as do their responsibilities. Where public safety is primary, the “authority having jurisdiction” may be a federal, state, local or other regional department or individual such as a fire chief, fire marshal, chief of a fire prevention bureau, labor department, health department, building official, electrical inspector, or others having statutory authority. For insurance purposes, an insurance inspection department, rating bureau, or other insurance company representative may be the “authority having jurisdiction.” In many circumstances the property owner or his designated agent assumes the role of the “authority having jurisdiction”; at government installations, the commanding officer or departmental official may be the “authority having jurisdiction.”

Combustible. Any material that, in the form in which it is used and under the conditions anticipated, will ignite and burn.

Combustible Liquid. A liquid having a flash point at or above 100°F (37.8°C). (*See NFPA 30, Flammable and Combustible Liquids Code.*)

Fire Area. That portion of a building or plant that is separated from other areas by fire barriers.

Fire Barrier. Those components of construction (walls, floors, or floor/ceiling assemblies and their supports, including beams, joists, columns, penetration seals or closures, fire doors, and fire dampers) that are rated by approval laboratories in hours of resistance to fire and are used to prevent the spread of fire.

Fire Brigade. As used in this standard, refers to those persons trained in plant fire fighting operations.

Fire Door. A door assembly rated in accordance with NFPA 252, *Standard Method of Fire Tests of Door Assemblies*, and installed in accordance with NFPA 80, *Fire Doors and Fire Windows*.

Fire Loading. The amount of combustibles present in a given situation, expressed in Btu per square foot.

Fire Prevention. Measures directed towards avoiding the inception of fire.

Fire Protection. Methods of providing for fire control or fire extinguishment.

Fire Protection Manager. The person directly responsible for the fire prevention and fire protection program at the plant.

Fire Rated Penetration. An opening in a fire barrier for the passage of pipe, cable, duct, etc., that has been sealed so as not to reduce the integrity of the fire barrier.

Fire Resistance Rating. The time, in minutes or hours, that materials or assemblies have withstood a fire exposure as established in accordance with the test procedures of NFPA 251, *Standard Methods of Fire Tests of Building Construction and Materials*.

Fire Zone. Subdivisions of fire areas in which fire detection and/or suppression systems provide alarm information indicating the location of fire at a central fire control center.

Flame Spread Rating. A relative measurement of the surface burning characteristics of building materials when tested in accordance with NFPA 255, *Standard Method of Test of Surface Burning Characteristics of Building Materials*.

Flammable Liquid. Any liquid having a flash point below 100°F (37.8°C) and having a vapor pressure not exceeding 40 psi (276 kPa) absolute pressure at 100°F (37.8°C).

Labeled. Equipment or materials to which has been attached a label, symbol or other identifying mark of an organization acceptable to the “authority having jurisdiction” and concerned with product evaluation, that maintains periodic inspection of production of labeled equipment or materials and by whose labeling the manufacturer indicates compliance with appropriate standards or performance in a specified manner.

Limited Combustible. A building construction material that, in the form in which it is used, has a potential heat value not exceeding 3500 Btu per pound (8141 kJ/kg) and either has a structural base of noncombustible material with a surfacing not exceeding a thickness of $^1/_8$ in. (3.2 mm) that has a flame spread rating not greater than 50, or other material having neither a flame spread rating greater than 25 nor evidence of continued progressive combustion, even on surfaces exposed by cutting through the material on any plane. (*See NFPA 220, Standard on Types of Building Construction.*)

Listed. Equipment or materials included in a list published by an organization acceptable to the "authority having jurisdiction" and concerned with product evaluation, that maintains periodic inspection of production of listed equipment or materials and whose listing states either that the equipment or material meets appropriate standards or has been tested and found suitable for use in a specified manner.

NOTE: The means for identifying listed equipment may vary for each organization concerned with product evaluation, some of which do not recognize equipment as listed unless it is also labeled. The "authority having jurisdiction" should utilize the system employed by the listing organization to identify a listed product.

Noncombustible Material. A material that, in the form in which it is used and under the conditions anticipated, will not ignite, support combustion, burn, or release flammable vapors when subjected to fire or heat. Materials reported as noncombustible, when tested in accordance with ASTM E136, *Test for Behavior of Materials in a Vertical Tube Furnace at 750°C*, shall be considered noncombustible materials.

Shall. Indicates a mandatory requirement.

Should. Indicates a recommendation or that which is advised but not required.

1-4 Introduction and Special Problems Relating to the Protection of Light Water Nuclear Electric Generating Stations.

1-4.1 General Introduction.

Fire protection is both an art and a science. Perfection and practice in the art is the objective, with fire prevention being the ultimate goal. Fire prevention in the absolute sense is only possible where there is no combustible material to fuel a fire. The presence of combustible material creates a fire potential, no matter how slight. Thus, fire prevention must, as a first priority, consider the presence of any combustible material as a variance.

The total elimination of combustible material is seldom possible; therefore, fire protection requires additional measures to limit the consequences of fire.

A defense-in-depth philosophy of fire prevention, control, and extinguishment shall be adopted and implemented to minimize and mitigate the effects of fire and reduce hazards to personnel and property damage to acceptable minimums.

A well-balanced fire protection program includes prevention, detection, extinguishment of fires, safety to life, and preservation of property. The protection of the environment and of the public against nuclear hazards takes priority over that of the plant itself and is addressed by the appropriate regulatory agencies. However, the size of nuclear power plants makes the economic impact of a forced outage such that protection measures must be extended to include provisions to assure their continued operation.

1-4.2 Special Considerations in Fire Protection Encountered at Light Water Nuclear Power Plants.

Consideration of the need for nuclear safety results in several areas of fire protection emphasis unique to the nuclear electric generating station; for example:

(a) Reactor shutdown systems.

(b) Cooling system integrity.

(c) Filtering system integrity.

(d) Ventilating system integrity.

NOTE: *See Appendix B.*

1-4.3 Defense-in-depth.

1-4.3.1 Light water nuclear power plants use the concept of defense-in-depth to achieve the high degree of safety required in the nuclear safety systems of the plant. This concept shall be extended to fire protection for the remaining areas of the plant.

1-4.3.2 With respect to the fire protection program the defense-in-depth principle is aimed at achieving an adequate balance in:

(a) Preventing fires from starting.

(b) Detecting fires quickly and suppressing those fires that occur, thereby limiting damage.

(c) Designing the plant to limit the consequences of fire.

NOTE: No one of these echelons can be perfect or complete by itself. Strengthening any one can compensate in some measure for weaknesses, known or unknown, in the others.

1-4.4 Fire Protection Management Program.

The fire protection program for a nuclear power plant shall cover design features, personnel, procedures, plans, and equipment. Senior management participation in this program shall begin with early design concepts and plant layout and continue through plant operation. In order to effectively develop and conduct this program, a fire protection manager shall be appointed at the conceptual stage of the project. The manager shall be selected on the basis of education, experience, and advancement as an industrial fire protection engineer. The manager shall establish liaison with all internal departments, with all authorities having jurisdiction, and with the public fire department.

1-5 Units.

Metric units of measurement in this standard are in accordance with the modernized metric system known as the International System of Units (SI). One unit (liter), outside of but recognized by SI, is commonly used in international fire protection. If a value for measurement as given in this standard is followed by an equivalent value in other units, the first stated is to be regarded as the requirement. A given equivalent value may be approximate.

Chapter 2 Functional Subdivisions of the Plant Layout

2-1

Safety to the lives of on-site personnel, protection of property, and continuity of power production as affected by the possibility of fires shall be given appropriate consideration in the general arrangement of the nuclear power plant. For the purposes of fire hazard analysis the plant component facilities shall be divided into primary facilities, secondary facilities, and support facilities as follows:

NOTE: The nuclear power plant will generally consist of the following functional facilities, which would be expected to vary in their physical relationship to each other from plant to plant.

(a) Typical Primary Facilities.

Reactor Building. Houses the reactor within a containment structure and its integral or freestanding shield.

Reactor Auxiliary Building. Contains reactor auxiliary and emergency core cooling system (ECCS) equipment.

Control Building. Houses the main and auxiliary control panels, emergency switchgear, and batteries.

Turbine Building. Houses the turbine generator and turbine generator auxiliaries.

Steam Generator Building. Houses the steam generator.

Intake Pumping Station. Houses the condenser circulating water makeup pumps, the raw service water and fire protection pumps, and all necessary valves and strainers for these systems.

Electrical Switchyard. Encompasses the electrical transmission system coming into the site and leaving the site.

Emergency Power Generation Facility. That facility designed to provide on-site emergency power in the event of an off-site power failure.

Emergency Service Water Pumping Station. Houses the emergency service water pumps and all necessary valves, strainers, and electrical switchgear for these systems.

Condenser Circulating Water Pumping Station. Houses the condenser circulating water pumps, pump isolation valves, pump suction and discharge conduits, and associated electrical equipment.

Electrical Control and Communications Building. Houses the switchyard relays and terminal communications equipment and may act as a control center for the switchyard up until the time the main control room becomes operational.

Main Heat Rejection System. Includes cooling towers and facilities associated with spray ponds and canals.

Station Transformers. Those transformers that provide auxiliary power to the plant or transmit power from the plant.

(b) Typical Secondary Facilities.

Fuel Building. Inclusion of primary equipment in this building would require upgrading of the affected portions of the building to primary facility status.

Radwaste Building. Houses the equipment for processing radioactive waste from the plant.

Makeup Water Treatment Plant. Facility for producing high purity water before use in the reactor or its support systems.

Condenser Circulating Water Treatment Building. Houses the plant and condenser circulating water biocide treatment system.

Demineralizer Regeneration Building. Contains facilities for regeneration and cleaning of resins from the plant condensate polishing system.

(c) Typical Support Facilities.

Office Building. Houses the offices for the plant's administrative employees and contains plant records.

Service Building. Encompasses the guard house, main gate, and office space for the plant's security force.

Auxiliary Boiler Building. Contains boilers for providing heating steam and steam to operate plant auxiliary equipment during the time that the nuclear steam supply is not available.

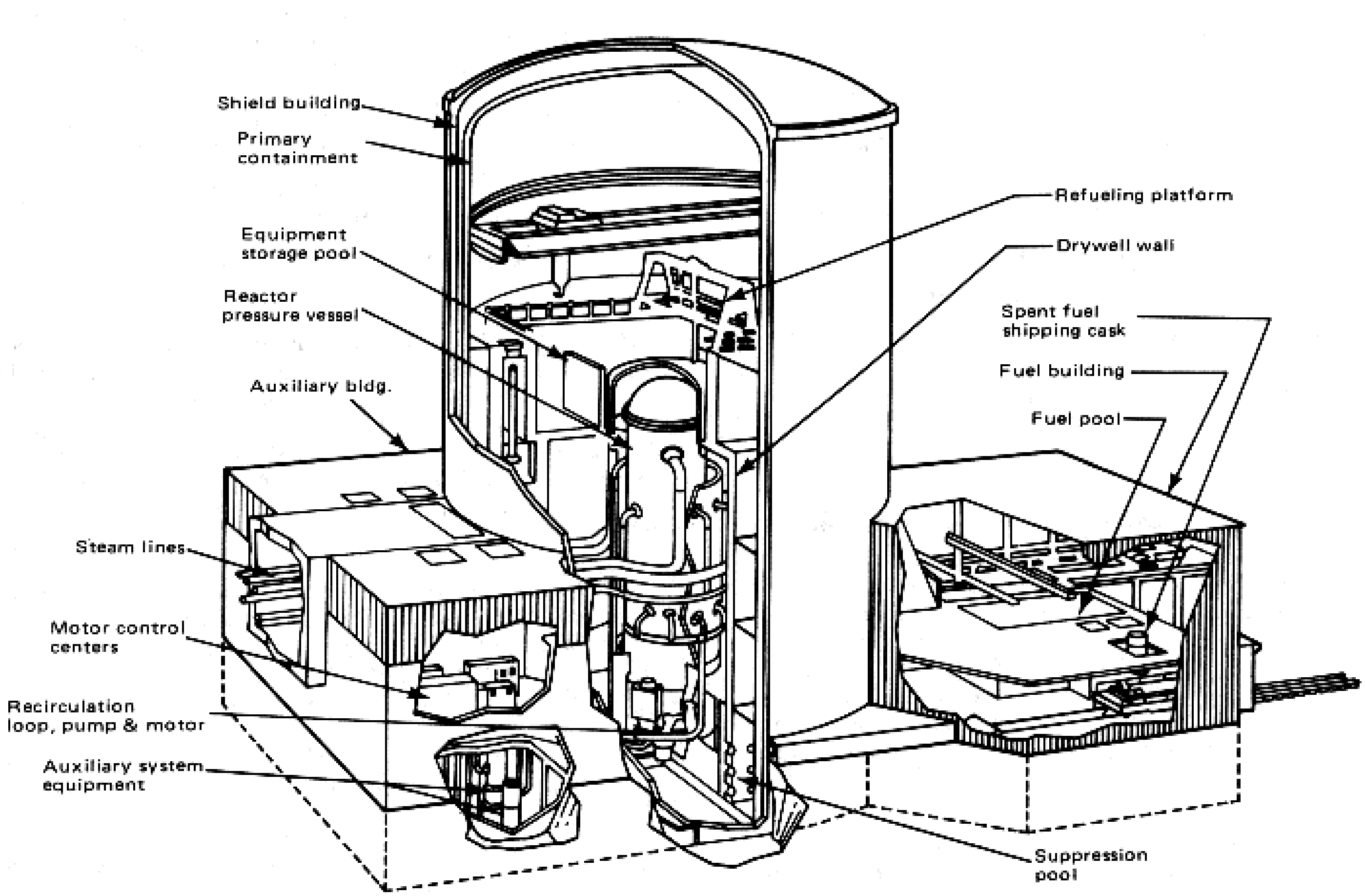


Figure 2-1 Mark III reactor building, fuel building, and auxiliary building.

2-2

For these three types of facilities, safety to the lives of on-site construction and operating personnel and loss of property shall be given consideration as specified in Chapter 17 and elsewhere in this standard.

2-3

For primary and secondary facilities the cost of lost revenue and replacement power in addition to property loss shall be factored into the fire hazard analysis for determining the cost/benefit ratio for selecting the appropriate fire protection systems.

2-4*

A fire hazard analysis shall be developed that will define the fire hazards that can exist and describe the loss limiting criteria to be used in the design of the facility. The fire hazard analysis shall take into consideration the basic data of the plant such as the functional subdivision of the facility, the controlled zones that have limited access, and the general plant layout of equipment or systems to develop the fire zone and the ratings of fire barriers.

Chapter 3 Inventory of Flammable and Combustible Materials

3-1

Combustible materials in both large and small concentrations will be present in nuclear power plants, as in most other industrial plants, and it shall be assumed that outbreaks of fire occur for a variety of reasons.

3-2

For the purpose of assessing the fire loading, an inventory of all flammable and combustible materials shall be made for each fire area, identifying the location, type, quantity, and form of the materials. The materials shall be classified into:

(a) *Flammable and Combustible Materials.* Typical examples of flammable and combustible materials found in a nuclear power plant are:

Conventional fuels for emergency power units, auxiliary boilers, etc.
Lubricants and hydraulic oil.
Insulating materials (thermal and electric).
Building materials (incl. PVC and other plastics).
Filtering materials (e.g., oil bath filters, charcoal, etc.).
Cleansing materials.
Paints and solvents.
Packaging materials (e.g., bitumen, etc.).
Neutron shields (if organic materials).
Clothing.

(b) *Flammable Gases.* Typical examples of flammable gases found in a nuclear power plant are:

Hydrogen for generator cooling, for coolant conditioning of gas-cooled reactors, and from battery charging.

Propane or other fuel gases.

O_2 and H_2 by radiolysis in the core and addition of H_2 for improved recombination.

Gas for cutting and welding.

(c) *Combustible Radioactive Substances.* Typical examples of radioactive substances external to the reactor are:

Sealed radioactive materials, such as irradiated and/or plutonium containing fuel elements, irradiated control rods, neutron sources, etc.

Unsealed radioactive material, such as ion exchanger fillings and filter cartridges that have become loaded with radioactive substances, radwaste materials, etc.

3-3

While assessing the hazardous substances, ways and means of transporting the supplies of consumable goods on the site shall be considered.

3-4

Temporary but predictable and repetitive concentrations of combustible materials shall also be considered. These may include:

(a) Replacement of lubricating or hydraulic oils.

(b) Repainting equipment or structures.

(c) Replacement of combustible filter materials.

(d) Scaffolding or dunnage necessary to maintain or replace equipment.

(e) Spare equipment in shipping crates or boxes awaiting installation.

Chapter 4 Control of Combustible Material

4-1

Combustibles, other than those that are an inherent part of operation, shall be restricted to protected compartments or spaces.

4-2

As part of the protective measures, consideration shall be given to reducing the fire loading of contents in primary or secondary facilities by reducing the amount of combustible materials, wherever possible, as indicated in the following design features:

(a) Provision of separate piping systems for the lubricating system and control system of the turbine generators.

(b) Use of an approved low hazard synthetic hydraulic fluid in the control systems.

(c) Use of approved noncombustible insulation materials on components.

4-2.1

Flammable and combustible liquid storage and use shall be in accordance with NFPA 30, *Flammable and Combustible Liquids Code*. Where oil-burning equipment, stationary combustion engines, or gas turbines are used, they shall be installed and used in accordance with NFPA 31, *Standard for the Installation of Oil-Burning Equipment*, or NFPA 37, *Standard for the Installation and Use of Stationary Combustion Engines and Gas Turbines*, as appropriate.

4-2.2 Hydrogen.

The storage and use of hydrogen shall be in accordance with NFPA 50A, *Standard for Gaseous Hydrogen Systems at Consumer Sites*.

4-2.3

Flammable and combustible liquid and gas piping shall be in accordance with ANSI B31.1 or ANSI B31.7, including Addenda a-1972, b-1971, and c-1971, as applicable.

Chapter 5 Construction Materials and Fire Loading in Buildings

5-1

The use of plastics such as polyurethane and polyvinyl chloride (PVC) shall be minimized and used generally at locations totally inaccessible to ignition and effects of fire exposure.

NOTE: Halogenated plastics, such as polyvinyl chloride (PVC), release chlorine and hydrogen chloride gas during a fire; these gases are toxic and corrosive.

5-2

Construction materials for nuclear power plants shall be classified by at least one of the following tests:

(a) NFPA 255, *Standard Method of Test of Surface Burning Characteristics of Building Materials*.

(b) NFPA 251, *Standard Method of Fire Tests of Building Construction and Materials*.

5-2.1

Certain materials of construction that do not meet the definition of noncombustible or limited combustible may have to be used in a nuclear power plant, and thus the location in the plant, the amount exposed to ignition, and the proposed fire protection system shall be justified in writing and the approval of the plant fire protection manager and the authority having jurisdiction shall be obtained.

5-3

Wall and structural components, thermal insulation materials, radiation shielding materials, and soundproofing shall be noncombustible, limited combustible, or listed by a testing laboratory for flame spread, smoke, and fuel contribution of 25 or less in its use configuration.

5-4

Suspended ceilings, including light diffusers, and their supports shall be of noncombustible or limited combustible construction. Electrical wiring above suspended ceilings shall be in metallic conduit or solid bottom, solid covered ferrous raceways. Otherwise concealed spaces shall be devoid of combustibles.

5-5

Roof coverings shall be Class A as determined by tests described in NFPA 256, *Standard Methods of Fire Tests of Roof Coverings*. Metal roof deck construction shall be Class I (Factory Mutual Approved) or “fire-acceptable” (as tested by Underwriters Laboratories Inc.).

5-6

Transformers installed inside of buildings shall be either dry type or insulated and cooled with an approved liquid, unless installed in vaults in accordance with Article 450 of NFPA 70, *National Electrical Code*.®

5-7

Cooling towers constructed of combustible or nonapproved construction shall be protected with deluge sprinkler systems in accordance with NFPA 214, *Standard on Water-Cooling Towers*. Fire hydrants shall be operational at the cooling tower site prior to beginning construction activities.

NOTE: Since cooling towers can be vital to the operation of the plant and reconstruction can be lengthy, noncombustible construction should be used.

Chapter 6 General Building Arrangement

6-1 General Fire Area Requirements.

6-1.1

The nuclear power plant shall be subdivided into separate fire areas to minimize the risk of spread of fire and the resultant consequential damage from corrosive gases, fire suppression agents and smoke and contamination from radioactive substances. In addition, subdivisions shall provide access for manual fire suppression activities.

6-1.2

In multi-unit plants, each unit shall be separated from the other either by distance or fire barriers. The distance or fire barrier rating shall be determined from the fire hazard analysis. (*See NFPA 80A, Recommended Practice for Protection of Buildings from Exterior Fire Exposures*.)

6-2 Specific Fire Separation Requirements.

6-2.1

An approved fire barrier having a fire resistance rating of 3 hours, with automatic- or self-closing fire doors having a fire protection rating of 3 hours, and with approved penetration protection, shall be provided as follows:

(a) To separate all contiguous buildings, such as turbine, reactor containment, auxiliary fuel handling, control, radwaste, service, administration, and other areas as dictated by reactor design and fire hazard analysis.

(b) To isolate turbine generator lube oil conditioning or system room and lube oil storage tank from turbine buildings and adjacent areas.

(c) To isolate emergency diesel generator rooms or buildings (emergency power generating areas) from each other and adjacent plant areas.

(d) To separate diesel fire pumps from other pumps in the same pumphouse.

(e) To separate all areas with concentrations of cables, such as cable spreading rooms, cable tunnels, cable penetration areas, cable shafts or chases, included within the reactor containment, from adjacent areas.

(f) To isolate auxiliary boiler rooms from adjacent areas.

6-2.2

Where fire barriers are constructed to prevent vertical spread of fire, stairways, elevator shafts, and trash chutes shall be enclosed with walls or partitions having a fire resistance rating of 2 hours. Openings in such walls or partitions shall be protected with approved automatic- or self-closing fire doors having a fire protection rating of $1^1/_2$ hours.

6-2.3

Buildings shall be protected from exposure fires involving oil filled transformers by locating the transformer casing, conservator tank, and cooling radiators at least 50 ft (15.2 m) from buildings or by providing a two-hour fire barrier between transformers and exposed buildings (*see Figure 6-2.3*). A one-hour fire barrier or a distance of 30 ft (9.1 m) shall be provided between adjacent transformers. Means shall be provided to contain oil spills.

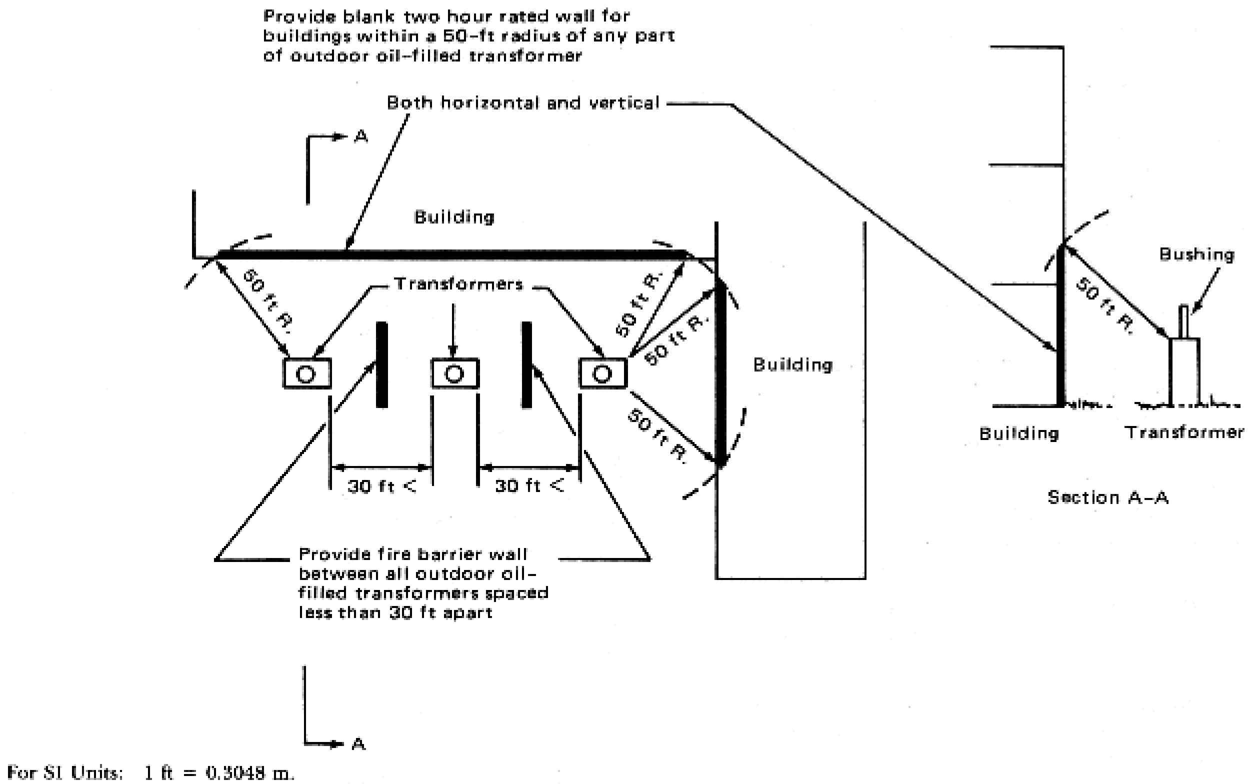


Figure 6-2.3.

6-3 Protection of Openings in Fire Barriers.

6-3.1 Electrical and Mechanical Penetrations.

Where electrical or mechanical equipment, other than ventilation ducts, must penetrate a fire barrier, the penetration shall be sealed (firestopped) with a material or device that maintains the required fire resistance rating of the fire barrier. The penetration seal (fire stop) shall be qualified in accordance with NFPA 251, *Standard Methods of Fire Tests of Building Construction and Materials*, except as modified herein:

(a) Temperatures on the unexposed surfaces of the penetration seal (fire stop) shall be measured and reported to the authorities having jurisdiction. The temperatures on the unexposed side for the metallic parts of the penetration (e.g., cable trays, conductors, pipe, etc.) shall also be measured and reported to the authorities having jurisdiction. The results of the test shall be incorporated into the plant's fire hazard analysis. (*See Section 2-4.*)

(b) Immediately following the termination of the fire endurance test a hose stream test shall be conducted using the NFPA 251 solid-stream test or a spray-stream test conforming to the following criteria:

1. Spray nozzle that produces a long-range, narrow-angle (not exceeding 30 degrees) high velocity spray.

2. Nozzle shall discharge a minimum of 75 gpm at 75 psi at 10 ft (4.7 liters/sec at 517 kPa at 3 m) from the test specimen.

3. Duration of application shall be not less than $2^1/_2$ minutes for every 100 sq ft (9 m^2) of area.

(c) The penetration seal (fire stop) shall be determined acceptable provided that:

1. Fire does not propagate to the unexposed side of the test assembly nor shall there be any visible flaming on the unexposed side.

2. Temperature readings on the unexposed side shall not be high enough to ignite combustible material as evaluated in the fire hazard analysis.

3. Penetration seal does not permit projection of water from hose stream test.

NOTE: If electrical or mechanical chases or shafts pass through a fire area without opening into that area, the penetration seals at fire barriers are not required provided the chases or shafts are enclosed with assemblies having fire resistance ratings not less than those of the fire barriers through which they pass.

6-3.2 Penetrations for Ventilation Ducts.

Where ventilation ducts must penetrate fire barriers, the ducts and opening protections shall comply with the provisions of Chapter 7 of this standard.

6-4 Reliability Considerations.

6-4.1

In accordance with the scope of this standard, it shall be recognized that continuing power production consideration dictates additional fire subdivision of the plant beyond that required for nuclear safety.

NOTE 1: The subdivision into fire areas for redundant nuclear safety systems is covered by other documents. (*See Appendix B.*)

NOTE 2: A fire that might be capable of damaging only one division of a redundant system, and therefore be acceptable from the standpoint of nuclear safety, may not be acceptable from a standpoint of forced plant outage. Additional fire protection systems or fire barriers may be required.

6-4.2

When evaluating the length of plant outage, as a result of possible fire, consideration shall be given to the length of time required to satisfy the demands of all of the authorities having jurisdiction for examining causes of the fire, planning of the repairs and reconstruction, testing, and documentation of the adequacy of the restoration process.

6-4.3 Cable Construction.

6-4.3.1 Cable insulating materials represent a major source of fire loading throughout the plant, and special consideration shall be given to their installation and protection.

6-4.3.2 As a minimum requirement, cable construction shall meet the fire and flame test requirements of IEEE No. 383. Meeting the requirements of IEEE No. 383 shall not eliminate the need for protection as specified in this standard.

Chapter 7 Heating, Ventilating, and Air Conditioning

7-1 Introduction.

Ventilation of a nuclear power plant involves balanced air differentials between plant areas, comfort ventilation, and heat removal from areas where heat is generated by equipment. This need also includes fire area isolation and smoke removal equipment, as well as equipment for filtering radioactive gases. The design of ventilation systems is further complicated by the seismic, tornado, and missile criteria for building penetrations.

7-2 Basic Standards.

NFPA 90A, *Standard for the Installation of Air Conditioning and Ventilating Systems*; NFPA 91, *Standard for Exhaust Systems for Air Conveying of Materials*; and NFPA 204M, *Guide for Smoke and Heat Venting*, are the basic standards that shall be followed for the design, installation, and operation of the ventilation systems necessary for normal and emergency operation of the plant except as modified below.

7-3 General Requirements.

7-3.1 Smoke and Corrosive Gas Removal.

7-3.1.1* Automatic shutdown of ventilation systems by temperature or smoke detectors as prescribed by applicable NFPA standards in the following buildings shall be consistent with nuclear safety and safety of on-site personnel:

(a) Reactor building.

(b) Auxiliary building.

(c) Control building.

(d) Turbine building.

(e) Intake pumping station.

(f) Emergency service water pumping station.

(g) Condenser circulating water pumping station.

(h) Electrical control and communications building.

(i) Fuel building.

(j) Emergency power generating building.

7-3.1.2 Smoke, corrosive gases, and the nonradioactive substances that might be freed by the fire shall be vented from their place of origin directly to a safe location. Radioactive materials that might be released by the fire shall be confined, removed from the exhaust ventilation air stream, or released under controlled conditions.

7-3.1.3 Ventilation systems designed to exhaust smoke or corrosive gases shall be evaluated to ensure that inadvertent operation or failures will not violate the controlled areas of the plant design.

7-3.1.4 Smoke ventilation shall be provided for fire areas based upon the fire hazard analysis.

NOTE 1: Separate smoke ventilation systems are preferred; however, smoke venting can be integrated into normal ventilation systems using automatic or manually positioned dampers and motor speed control.

NOTE 2: The lack of smoke and heat venting in areas of relatively high combustible loading can result in significant damage to structural components.

NOTE 3: Automatic or manual actuation of smoke and heat venting will be determined by the fire hazard analysis.

Smoke ventilation from areas that may contain radioactive substances shall not be ventilated outside the building. These smoke ventilation systems shall be connected to gas treatment systems to preclude release of radioactive substances.

7-3.1.5 The fresh-air supply intakes to all areas shall be located remotely from the exhaust air outlets and smoke vents of other fire areas to minimize the possibility of contaminating the intake air with the products of combustion.

7-3.1.6 Enclosed stairwells shall be designed to minimize smoke infiltration during a fire.

NOTE: Stairwells serve as escape routes and fire fighting access routes. Suitable methods of ensuring a smoke-free stairwell include pressurization of stairwells (*see NFPA 90A*) and the construction of smokeproof towers (*see 5-2.3 of NFPA 101,® Life Safety Code.®*)

7-3.1.7 When natural-convection ventilation is used, a minimum ratio of vent area to floor area shall be one to 200 except in oil hazard areas where a one to 100 ratio shall be provided.

NOTE: When mechanical ventilation is used, 300 cfm (8.5 m^3/min) is equal to 1 sq ft (0.09 m^2) of natural convection vent area.

7-3.1.8 To prevent corrosion that might be caused by direct release of chemicals in case of fire, the acids and alkalines used for the primary coolant treatment plant and stored in appreciable quantities on the site shall be protected so as not to increase the risk of damage in case of a fire.

7-3.1.9 The power supply and controls for mechanical ventilation systems shall be located outside the fire area served by the system or protected from fire damage.

7-3.2 Duct Systems.

7-3.2.1 Plastic ducts, including fire retardant types, shall not be used for ventilating systems.

7-3.2.2 Ventilation ducts that pass through fire areas that they do not serve shall not degrade the fire integrity of the fire rated enclosure.

NOTE: Fire dampers or fire doors compatible with the rating of the barrier may be required at the duct penetrations to the fire area. (*See 7-3.2.3.*)

7-3.2.3 Fire dampers shall be provided to prevent the passage of smoke, heat, or flame through ventilation ducts from one area to another.

7-3.2.3.1 Approved fire dampers having a rating of $1^1/_2$ hours shall be installed where ventilation ducts penetrate fire barriers having a required fire resistance rating of 2 hours or less. Where ventilation ducts penetrate required 3-hour fire barriers, approved fire dampers having a fire protection rating of 3 hours shall be installed.

Exception: Fire dampers are not required for ventilation duct penetrations where shutdown of the ventilation system is not allowed.

7-3.2.4 Fire dampers shall be equipped with thermal elements. The closure of fire dampers shall be guaranteed by mounting the damper directly into the separating wall or by protecting the duct up to the damper according to the fire resistance of the separating wall structure.

7-3.2.5 Interconnections of individual fire areas via the ventilation system shall be avoided insofar as possible. Where this is not possible, the necessary precautions shall be taken to prevent the spread of smoke and fire by such routes.

NOTE: Fire dampers in the interconnecting ventilation ducts should be provided when the ventilation system cannot be sectioned off in the normal manner. (*See 7-3.2.3.*)

7-3.2.6 False floors or suspended ceilings shall not be employed as common pressure equalizing chambers for redundant ventilation systems but may be used for distribution of air to the corresponding room.

7-3.3 Filters.

7-3.3.1 Air entry filters shall have noncombustible filter media. They shall produce a minimum amount of smoke (UL Class 1) when subjected to heat. In order to decrease the fire hazard of these filters and of oil bath type filters, only approved fire-resistive adhesives and oils with an open-cup flash point equal to or greater than 464°F (240°C) and that do not produce appreciable smoke shall be used. HEPA filters shall meet the requirements of UL 586.

7-3.3.2 Fire suppression systems shall be installed to protect filters that collect combustible material, unless the elimination of such protection is justified by the fire hazard analysis.

7-3.4 Special Equipment for Emergency Personnel.

Self-contained breathing apparatus using full-face, positive-pressure masks approved by NIOSH (National Institute for Occupational Safety and Health) shall be provided for fire brigade and control room personnel.

NOTE: Control room personnel may be furnished breathing air by a manifold system piped from a storage reservoir, if practical. Service or operating life should be a minimum of one-half hour for the self-contained units. At least two extra air bottles should be located on site for each self-contained breathing unit. In addition, an on-site 6-hour supply of reserve air should be provided and arranged to permit quick and complete replenishment of exhausted supply air bottles as they are returned. If compressors are used as a source of breathing air, only units approved for breathing air should be used.

Chapter 8 Fire Prevention Measures

8-1 Administrative Procedures and Controls.

NOTE: This section provides criteria for development of administrative procedures and controls necessary for the execution of the fire prevention and protection activities and practices for the operating plant. Included herein are the minimally accepted actions required of cognizant plant management to assure the performance of fire protection systems and personnel and the compliance with the fire prevention program.

8-1.1

The plant manager or delegated fire protection manager shall be responsible for assuring that the fire hazards analysis is periodically updated.

8-1.2

The plant manager or delegated fire protection manager shall be responsible for the following:

(a) Develop, implement, and periodically update as necessary a fire brigade plan in accordance with Chapter 14.

(b) Maintain housekeeping in such a manner so as to minimize the probability of fire causing loss of life or property damage.

(c) Develop, implement, and periodically update as necessary an emergency evacuation plan for all personnel.

(d) Develop, implement, and periodically update as necessary a welding and cutting safety procedure using NFPA 51B and NFPA 241 as guides. (*See Chapter 15.*)

(e) Restrict smoking and other sources of ignition to properly designated and supervised safe areas of the plant.

(f) Develop, implement, and periodically update as necessary a fire prevention surveillance plan integrated with periodic recorded rounds to all accessible unattended sections of the plant.

(g) Coordinate the periodic testing of all systems and equipment affecting fire prevention and fire protection in accordance with the applicable NFPA standards and/or the manufacturers'/installers' instructions and procedures to include maintenance of appropriate documentation.

(h) Develop an alternate protection plan for those instances when it becomes necessary to remove any fire protection equipment or system from service.

(i) Fire investigation and the coordination of all plant fire reporting. Responsibilities including reviewing fire reports, taking corrective action, and making the proper distribution of the reports.

(j) Conduct periodic inspections of the plant. A prepared checklist shall be used for the inspection. The areas of primary containment and high radiation areas normally inaccessible during plant operation shall be inspected as plant conditions permit but at least during each refueling outage. The results of each inspection shall be documented and retained for a period of two years.

8-1.3

Plant administrative procedures shall specify appropriate requirements governing the storage, use, and handling of flammable liquids and gases.

8-1.4

Plant administrative procedures shall specify appropriate requirements governing the control of electrical appliances, i.e., portable electrical heaters in critical areas.

8-1.5

The reduction and control of temporary fire loads in the plant is essential to provide defense-in-depth protection. As a minimum, plant administrative procedures shall require that the total fire loads, including temporary and permanent, will not exceed those quantities established for extinguishment by permanently installed fire protection systems and equipment except in approved controlled conditions. Under such conditions, the plant fire protection manager shall evaluate temporary fire loads using appropriate documented guidelines and shall be responsible for ensuring that applicable additional personnel and/or fire protection equipment is provided when limits are exceeded. The fire protection manager or designated representative shall conduct weekly walk-through inspections to ensure implementation of required controls. During major maintenance operations the frequency of these walk-throughs shall be increased to daily. These inspections shall be documented, and the records retained for a period of two years.

Transient fire loads, when allowed, shall be controlled and shall require the implementation of additional protective measures such as supplemental portable fire equipment, fire retardant impregnation, and fire watches, depending on the types and quantities of the transient combustibles and the potential fire exposure they present to the plant. Particular attention shall be given to the control of halogenated plastics. When the work is completed, the plant fire protection manager shall have the area inspected to confirm that the transient fire loads have been removed from the area. Extra equipment shall then be returned to its proper location. The results of this inspection shall be documented and retained for a period of two years.

8-1.6

Plant administrative procedures shall specify that all wood routinely used in the plant shall be approved pressure impregnated fire retardant type prior to being introduced into the plant.

8-1.7

Plant administrative procedures shall require an inplant review and prior approval of all work plans to assess potential fire hazard situations. Where such conditions are determined to exist special precautions shall be taken to define appropriate conditions under which the work is authorized.

8-2 Lightning Protection Measures for Buildings.

The plant shall be equipped with an approved lightning protection system. (*See NFPA 780, Lightning Protection Code.*)

8-3 Prevention Measures for Plant Equipment.

8-3.1

The ignition of leaked or spilled oil shall be minimized by:

(a) Keeping the oil from contact with hot parts of the steam systems (wall temperature ò ignition temperature), such as steam pipes and ducts, entry valve, turbine casing, reheater, and by-pass valve.

NOTE: Oil pipes should be located below steam lines.

(b) Using suitable electrical equipment.

(c) Sealing the insulation of hot plant components to prevent oil saturation.

(d) Use of concentric piping.

8-3.2

The ignition of gas shall be minimized by:

(a) Providing electrical installations suitable for hazardous (classified) locations as defined in Article 500 of NFPA 70, *National Electrical Code*, in those areas where the fire hazard analysis shows these locations to exist.

8-3.3

Ignition of flammable materials in auxiliary equipment shall be minimized by:

(a) Providing approved combustion safeguards on boilers and other fossil fuel-fired equipment in accordance with NFPA 85C, *Standard for the Prevention of Furnace Explosions/Implosions in Multiple Burner Boiler-Furnaces,* and NFPA 8501, *Standard for Single Burner Boiler Operation*.

(b) Constructing and installing equipment containing flammable or combustible liquids in accordance with NFPA 30, *Flammable and Combustible Liquids Code*, Chapter 5.

(c) Equipping all oil-filled transformers with:

1. High oil temperature limit switches in accordance with the manufacturer's recommendations, with an audible and visual signal or an automatic device to de-energize the transformer.

2. An overcurrent protection device.

3. A differential relay.

4. A gas detector and fault over-pressure relays with a warning signal and automated shut-down for equipment over 10 MW.

5. Lightning protection.

(d) Equipping generators with warning signals, automated shutdown, and the following protective devices:

1. Overvoltage or undervoltage.

2. Overcurrent.

3. Differential relays.

4. Reverse power relays.

5. Proper performance of systems providing cooling and sealing gas.

(e) Installing only air circuit breakers, low oil content circuit breakers, or circuit breakers filled with sulfur hexafluoride (SF_6) or similar nonflammable fluids when located indoors.

8-4 Prevention Measures for Operation of the Plant.

(*See Chapter 15*.)

Chapter 9 Fire Signaling Systems

9-1 Fire Signaling Systems.

9-1.1

Fire signaling systems shall be provided in all areas of the plant as required by the fire hazard analysis. The requirements of this chapter constitute the minimum acceptable protective signaling system functions when used in conjunction with NFPA 72, *Standard for the Installation, Maintenance, and Use of Protective Signaling System*. All components of the fire signaling systems shall be of an approved type.

9-1.2

The signaling system's initiating device and signaling line circuits shall provide emergency operation for fire detection, fire alarm, and water flow alarm during a single break or a single ground fault.

NOTE: See NFPA 72 for definitions of signaling line circuits and initiating device circuit.

9-1.3

Fire signaling equipment used for fixed fire suppression systems shall give audible and visual alarm and system trouble annunciation in the plant control room and the plant security office. A general alarm annunciation would be acceptable in one of the two locations. Local alarm shall be provided in the affected fire zone and to other locations as may be required by the authority having jurisdiction.

9-1.4

Audible signaling appliances shall produce a distinctive sound, used for no other purpose. (*See NFPA 72*.) Audible signaling devices shall be located and installed so that the alarm can be heard above ambient noise levels.

Exception: Visual signaling appliances may be used to supplement audible appliances in the protected areas. (See Section 9-3.)

9-1.5

Plant control room or plant security personnel shall be trained in the operation of all fire signaling systems used in the plant. (*See 9-1.3*.) This training shall include the ability to identify any alarm zone or fire protection system that is operating.

9-1.6

Fire signaling equipment and actuation equipment for the release of fixed fire suppression systems shall be connected to power supply sources in accordance with the requirements of NFPA 72.

9-1.7

Manual fire alarm boxes shall be installed as required by the fire hazard analysis. (*See NFPA 72*.) Where manual release devices are installed for the purpose of releasing an extinguishing agent in a fixed fire suppression system, they shall be clearly marked for that purpose.

9-1.8

All signals shall be permanently recorded in accordance with NFPA 72.

9-2 Fire Detectors.

Automatic fire detectors shall be selected and installed in accordance with:

(a) NFPA 72E, *Standard on Automatic Fire Detectors*.

(b) The design parameters required as a result of the fire hazard analysis of the plant area.

(c) The additional requirements of this standard.

When the fire hazard analysis shows that fire detection is needed, Table 9-2 shall be used in selecting the type of detectors to be installed. Additional considerations prior to selection shall include (1) response characteristics, (2) maintenance requirements, (3) testing requirements, (4) adaptability to environment, and (5) accessibility.

NOTE: This table is intended to show the types of fire detectors that have application to hazard areas listed. In some cases, more than one type of detector should be considered by the designer for application in a specific hazard area. Within each generic type of detector (*see NFPA 72E for detector types*) differences among specific principles of operation may suggest preference of a specific detector for specific hazards.

Table 9-2

Plant Area	Combustible Loading/ Fire Hazard (See Note 1)	Anticipated Fire Development	Obstruction Congestion or Construction	Ceiling Height	Venti-lation	Radioactive Contamina-tion or Corrosion	Ambient Tempera-ture	Acceptable Detector Choice (See 9-2) (See Note 2) *S	*T	*F	*O
Battery Rooms	Cable Insulation Plastic Battery Cases, Wood in Racks, Hydrogen Gas	Hydrogen Explosive or Slow	Low	Low	Moderate	Potentially Corrosive	Normal	X		X	X
Cable Penetra-tion and Spreading Rooms	Cable Insulation, Relays, MCC	Slow	High/Moderate	Low/ Moderate	Moderate	N/A	Normal	X	X		
Cable Tunnels	Cable Insulation	Slow	High	Low	Variable	Variable	Variable	X	X		
Cable Shafts and Chases	Cable Insulation	Slow	Variable	N/A	Variable	Variable	Variable	X	X		
Cable Tray Run Concentrations	Cable Insulation	Slow	Variable	Variable	Variable	Variable	Variable	X	X		
Combustible (Charcoal) Filters	Charcoal	Slow	High	Low	Variable	Potential Radiation	Normal		X		
Computer Rooms (Includ-ing Under Floor Space)	Cable Insulation, Class A Combustibles	Slow/Fast	Moderate/High	Low	High	N/A	Normal	X			
Control Room	Cable Insulation, Class A Combustibles	Slow/Moderate	Moderate/High	Low	Moderate/ High	N/A	Normal	X			
Control Room Above Ceiling	Cable Insulation, Ducts, Lighting Equipment	Slow	Moderate/High or Inaccessible	Low	Variable	N/A	Normal	X			
Diesel Fire Pump Room	Oil, Plastic Bat-tery Cases, Cable Insulation	Fast	Low/Moderate	Variable	Variable	Potentially Corrosive	Variable	X	X	X	
Diesel Generator Rooms	Oil, Cable Insulation	Fast	Low/Moderate	Variable	Moderate/ High (During Operation)	N/A	Variable	X	X	X	
Diesel Fuel Day Tank Rooms	Oil	Fast	Moderate/High	Low	Low/ Moderate	N/A	Normal	X	X	X	
Diesel Fuel Storage Tank If Not Buried	Oil	Fast	Low	Non-out-doors Variable Indoors	Non-out-doors Variable Indoors	N/A	Normal	X	X	X	
Filter Rooms and Plenums	Charcoal	Slow/Moderate	Low/Moderate	Variable	Variable	Potential Radiation	Normal	X	X		
In-Plant Flam-mable Liquid Storage Rooms	Low/High Flash Point Liquids	Fast	Moderate/High	Variable	Low/ Moderate	N/A	Normal	X	X	X	X
Fuel Oil Storage Tanks	Oils	Fast	Low	N/A Out-doors	N/A Out-doors	N/A	Normal		X	X	
[illegible] Oil Units	[illegible]	Fast	[illegible]	[illegible]	[illegible]	Potential Radiation BWR	[illegible]		X		

Plant Area	Combustible Loading/ Fire Hazard (See Note 1)	Anticipated Fire Development	Obstruction Congestion or Construction	Ceiling Height	Ventilation	Radioactive Contamination or Corrosion	Ambient Temperature	Acceptable Detector Choice (See 9-2) *S	*T	*F	*O
								(See Note 2)			
Instrument Rack Rooms	Cable, Possible Flammable Gas	Slow/Fast	Moderate/High	Variable	Low/ Moderate	Potential Radiation	Variable	X	X	X	
Laboratories	Chemicals, Gases, Liquid	Moderate/Fast	Low/Moderate	Low	Low/ Moderate	Potential Radiation	Normal	X	X		X
Oil Lines and Reservoirs at Steam Driven Equipment	Oil, Oil Soaked Insulation	Fast/Moderate	Low	Variable	Variable	None	Variable	X	X		
Reactor/Coolant Recirculation Pumps	Oil, Oil Soaked Insulation	Fast/Moderate	Moderate/High	Variable	Variable	Potential Radiation	High	X	X	X	
Record Storage Rooms	Class A	Slow	Low	Low	Low	None	Normal	X	X		
Relay Rooms/ Cabinets	Cable, Plastics	Slow	Moderate/High	Low/ Moderate	Low/ Moderate	None	Variable	X	X	X	
Switchgear Rooms	Cable, Electronics	Slow	Low/Moderate	Variable	Moderate/ High	None	Normal	X		X	
Transformer Outdoor (if Combustible Oil Filled)	Oil	Fast/Ultra Fast	Low	N/A	Outdoors	Weather Corrosive	Normal		X	X	
Transformer Indoor (if Combustible Oil Filled)	Oil, Cable	Fast/Ultra Fast	Moderate	Variable	Variable	None	Variable	X	X	X	
Turbine Building Beneath Operating Floor Where Oil Can Spread	Oil, Hydrogen Cable	Fast/Explosive	Variable	Variable	Variable	None-PWR Potential Radiation BWR	Moderate/ High		X	X	
Turbine Generator Governor Housing (if Combustible Fluid)	Lube Oil, Oil Soaked Insulation	Fast/Moderate	Low	N/A	None	None-PWR Potential Radiation BWR	High		X	X	
Turbine Generator Bearings-(Seals)	Oil, Oil Soaked Insulation	Fast/Moderate	Low	N/A	None	None-PWR Potential Radiation BWR	Moderate/ High		X	X	
Turbine Oil Piping Above Operating Floor	Oil	Fast	High	Low	None	None-PWR Potential Radiation BWR	High	X	X	X	
Generator Bearings, Seals (Below Operating Floor)	Lube Oil, Hydrogen	Fast/Ultra Fast	High	Variable	Low	None-PWR Potential Radiation BWR	Moderate		X	X	
Generator Bear-	Lube Oil,	Fast/Ultra Fast	Low	N/A	None	None-PWR	Moderate		X	X	

Turbine Generator Lube Oil Conditioning or System Room	Lube Oil	Fast	Moderate	Variable	Low/ Moderate	None-PWR	Moderate	X	X	X	

Table 9-2, continued

Plant Area	Combustible Loading/ Fire Hazard (See Note 1)	Anticipated Fire Development	Obstruction Congestion or Construction	Ceiling Height	Ventilation	Radioactive Contamination or Corrosion	Ambient Temperature	Acceptable Detector Choice (See 9-2) *S	*T	*F	*O
								(See Note 2)			
Turbine Generator Lube Oil Storage Room	Lube Oil, Possibly Hydrogen	Fast/Explosive	Moderate	Variable	Variable	None-PWR	Moderate	X	X	X	
Steam Valves (if Combustible Hydraulic Fluid)	Hydraulic Oil, Oil, Insulation	Fast/Moderate	Moderate/High	Variable	Variable	None-PWR Potential Radiation BWR	High		X	X	
Hydrogen Manifold Areas	Hydrogen	Fast/Explosive	Low	Variable	Variable	None-PWR	Normal		X	X	X
Hydrogen Storage Outdoor	Hydrogen	Fast/Explosive	None	N/A	N/A	N/A	Normal		X	X	X
Miscellaneous Flammable Gas Storage	Miscellaneous Gases	Fast/Explosive	None	Variable	Variable	N/A	Normal	X	X	X	X
Machine Shops	Various Class A and B	Moderate/Fast	None	Variable	Low	Possible Radiation	Normal	X	X		
Weld Shops	Various Class A and B (Gases)	Moderate/Fast	Moderate	Variable	Low/ Moderate	None	Normal		X		
Tool Cribs	Various Class A and B	Slow/Moderate	Moderate	Low	Low	None	Normal	X	X		
Warehouse Storage Rooms	Various Class A and B	Slow/Moderate	Moderate/High	Variable	Low	None	Normal	X	X		
Truck and Railroad Unloading Areas	Various Class A and B	Moderate/Fast	Moderate	Moderate/ High	Low	Potential Radiation	Normal		X		
Heating or Auxiliary Boiler Rooms	Fuel Oil	Moderate/Fast	Moderate	Variable	Variable	Moderate	None	X	X	X	
Offices	Various Class A	Slow/Moderate	Low	Low	Low	None	Normal	X	X		
Cooling Towers (Combustible)	Wood or Plastic	Moderate/Fast	High	N/A	High	Corrosion and Moisture	Normal		X		
Access Control Areas	Various Class A and B	Moderate/Fast	Moderate	Low	Variable	Potential Radiation	Normal	X	X		
Locker Rooms	Various Class A	Moderate	Low	Low	Low	None	Normal	X	X		
Low Radiation Waste Storage and Process	Various Class A Cable	Slow/Moderate	Low/Moderate	Variable	Low/ Moderate	Potential Radiation	Normal	X	X		
Anticontamination Clothing Storage and Cleaning	Class A	Moderate	Low/Moderate	Variable	Low Moderate	Potential Radiation	Normal	X	X		
New Fuel Storage Area	Plastic, Cable	Slow	Low	Variable	Low	Potential Radiation	Normal	X			
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	X		X	

NOTE 1: (comb, loading/fire hazard column)
The combustible loading for each fire area represents combustibles normally expected in these areas excluding transient combustibles, which shall be identified by the detailed fire hazard analysis of the respective plant area.
NOTE 2: "T" column under detectors
Automatic sprinklers, when selected as a suppression system from Table 10-1.2, also act as thermal, spot-type detectors. This could occur if sprinklers are used in a wet pipe, dry pipe, preaction wet pilot or preaction dry pilot configuration.
*Detector Designations: S — Smoke, T — Temperature, F — Flame, O — Other

9-3 Fire Signaling System Display and Supervision.

The fire signaling system display panel shall be located in the plant control room or the plant security office. Annunciation circuits connecting zone, main control, and remote annunciation panels shall be electrically supervised.

9-4 Maintenance, Inspection, and Acceptance Testing of Fire Signaling Systems.

Maintenance, inspection, and acceptance requirements shall be in accordance with appropriate NFPA standards for detection devices and signaling systems. The authority having jurisdiction shall be consulted on all alterations and additions to the system under its supervision.

9-5 Communications.

9-5.1

The plant public address system shall be available on a priority basis for fire announcements, directing plant fire brigades, and fire evacuation information.

9-5.2

Radio, telephone, or other 2-way communication systems shall be provided.

Chapter 10 Fire Suppression Systems

10-1 General.

10-1.1

Automatic suppression systems shall be provided in all areas of the plant as required by the fire hazard analysis. Except as modified in this chapter, the following NFPA standards shall be used:

NFPA 11, *Standard for Low Expansion Foam and Combined Agent Systems*

NFPA 11A, *Standard for Medium- and High-Expansion Foam Systems*

NFPA 12, *Standard on Carbon Dioxide Systems*

NFPA 12A, *Standard on Halon 1301 Fire Extinguishing Systems*

NFPA 12B, *Standard on Halon 1211 Fire Extinguishing Systems*

NFPA 13, *Standard for the Installation of Sprinkler Systems*

NFPA 15, *Standard for Water Spray Fixed Systems for Fire Protection*

NFPA 16, *Standard on the Installation of Deluge Foam-Water Sprinkler and Foam-Water Spray Systems*

NFPA 17, *Standard for Dry Chemical Systems.*

10-1.2

The extinguishing systems chosen shall be based on the design parameters required as a result of the fire hazard analysis. When the fire hazard analysis shows that a fixed extinguishing system is needed, Table 10-1.2 shall be used in selecting the type of system or combination of systems to be installed.

Table 10-1.2

Area or Hazard to Be Protected	Water Systems			Liquefied Compressed Gases			Foam Systems			Dry Chemical
	Automatic Sprinklers	Preaction Sprinklers	Deluge-Water Spray	Halon 1301	Halon 1211	Carbon Dioxide	Mech.	Foam-Water Systems	High Expansion	
Auxiliary Oil or Gas Boiler Room	X	X					X (oil)	X (oil)		X
Battery Rooms	X	X		X	X	X				
Cable Penetration Rooms and Spreading Rooms	X (Note 1)	X (Note 1)	X (Note 1)	X (Note 2)	X (Note 2)	X (Note 2)				
Cable Tunnels, Shafts, Chases, Cable Tray Run Concentrations	X (Note 1)	X (Note 1)	X (Note 1)	X (Note 2)	X (Note 2)	X (Note 2)				X (multipurpose only)
Combustible (Charcoal) Filters			X							
Computer Rooms (Including under floor space)	X	X		X		X (Note 4)				
Control Room		X		X						
Diesel Fire Pump Room	X									
Diesel Generator Rooms (Note 3)	X	X		X	X	X	X	X	X	X
Diesel Fuel Day Tank Rooms	X	X	X	X	X	X	X	X	X	X
Diesel Fuel Storage Tank, If Not Buried	X		X	X	X	X	X	X	X	X
Filter Rooms and Plenums	X	X	X							
Flammable Liquid Storage Areas	X		X	X	X	X	X	X	X	X
Fuel Oils Storage Tanks	X		X				X	X	X	X
Hydrogen Seal Oil Units			X							X
Instrument Rack Rooms				X	X	X				
Laboratories	X	X		X	X	X				
Oil Lines & Reservoirs at Steam Turbine Driven Equip. (if more than 50 gallons)	X	X	X	X (Note 5)	X (Note 5)	X (Note 5)				X
Reactor Coolant/Recirculation Pumps	X	X	X			X	X	X		X
Record Storage Rooms	X	X		X (Note 6)	X (Note 6)	X (Note 6)				
Relay Rooms/Cabinets	X	X		X	X	X				
Switchgear Rooms		X		X	X	X				
Transformer Outdoor (if combustible oil filled)			X							
Transformer Indoor (if combustible oil filled)	X	X	X	X	X	X				X
Turbine Bldg. Beneath Operating Floor Where Oil Can Spread	X	X					X	X		X
Turbine Generator Governor Housing (if combustible fluid)		X	X	X (Note 5)	X (Note 5)	X (Note 5)				X
Turbine Generator Bearings (seals)		X	X	X (Note 5)	X (Note 5)	X (Note 5)				X
Turbine Generator Lube Oil Conditioning or System Room	X	X	X	X	X	X	X	X	X	X
Turbine Generator Lube Oil Storage Rooms	X	X	X	X	X	X	X	X	X	X
Steam Valves (if combustible hydraulic fluid)			X			X				X
Staging, Storage and Warehousing Areas	X	X							X	
Truck and Railroad Bays (other areas of combustible										

NOTE 1: ...re used, means shall be provided for prompt actuation.
NOTE 2: Ceiling sprinklers may be required in addition.
NOTE 3: Release of extinguishing agent shall not be prevented if equipment is operating.
NOTE 4: Under floor only.
NOTE 5: Design concentrations shall be maintained during the entire coast down period.
NOTE 6: Combustible storage should be in metal cabinets.

10-1.3

Selection of extinguishing agent shall be based on:

(a) Type or class of hazard.

(b) Effect of agent discharge on critical equipment such as thermal shock, continued operability, water damage, over-pressurization, cleanup, etc.

(c) Health hazards.

10-1.4

A designated person(s) working in the plant shall be trained in the maintenance, inspection, operation, and emergency actuation of all fixed fire suppression systems installed in the plant, whether automatic or manual.

10-1.5*

Each fire suppression system shall be equipped with approved alarm devices, annunciated locally or in the hazard area. (*See 9-1.3.*)

10-1.6*

All shut-off valves controlling fire suppression systems (*see 10-2.2*) shall be supervised by one of the following methods:

(a) Electrical supervision with an audible signal annunciating in accordance with Chapter 9.

(b) Locking valves open.

10-2 Automatic Sprinkler and Water Spray Systems.

10-2.1

Where water is used as an extinguishing agent, systems shall be designed, installed, and maintained in accordance with the provisions of NFPA 13 and NFPA 15.

NOTE: Hydraulically calculated systems are preferred.

10-2.2

Each system shall have an independent connection to the plant yard main and be equipped with an approved indicating type control or shut-off valve.

NOTE: Multiple sprinkler and standpipe systems may be supplied by interior headers or fire protection loops. When provided, such headers or loops are considered an extension of the yard main system and should be provided with at least two connections to the yard main. The arrangement should be supplied and valved so that no single impairment can affect sprinkler and hose protection at the same time.

10-2.3

Drainage of all buildings shall be assessed to assure acceptable run-off or retention of fire protection water and to minimize damage.

NOTE 1: Equipment vulnerable to water damage should be placed on pedestals and floor openings should be curbed or sealed.

NOTE 2: The installation of a complete, properly engineered automatic sprinkler or water spray system in a building will generally reduce the draining and retention tank requirements, as compared to a building that relies primarily on manual fire fighting.

10-3 Liquefied Compressed Gas Suppression Systems.

10-3.1

In areas where appreciable Class C hazards exist and where the use of other agents might result in equipment malfunction or damage as determined by the fire hazard analysis, liquefied compressed gas extinguishing agent systems shall be installed. These systems, where required, shall be designed, installed, and maintained in accordance with the appropriate agent standard as follows:

Halon 1301 — NFPA 12A

Halon 1211 — NFPA 12B

Carbon Dioxide — NFPA 12.

10-3.2

When liquefied compressed gas extinguishing agent systems are used, they shall be automatically actuated by an approved method of detection meeting the requirements of NFPA 72 and NFPA 72E. To ensure rapid detection, particular attention shall be given to the choice of actuation means, the air flows usually involved, and the heat release rates for the hazard under fire conditions.

NOTE 1: For carbon dioxide total flooding systems that are automatically actuated in normally occupied areas, a predischarge alarm and time delay are required to allow for personnel evacuation of the area.

NOTE 2: Halon 1211 is not acceptable for total flooding use in normally occupied areas.

NOTE 3: Electrical equipment need not be de-energized prior to the discharge of these extinguishing agent systems, but shut-down is desirable if it can be accomplished.

10-4 Foam Systems.

10-4.1

Where fires involving flammable liquids and gases under pressure are likely, foam systems shall not be used. These systems, where required by the fire hazard analysis, shall be designed, installed, and maintained in accordance with the appropriate agent standard as follows:

Low Expansion Foam and Combined Agent Extinguishing Systems — NFPA 11

Medium- and High-Expansion Foam Systems — NFPA 11A

Deluge Foam-Water Sprinkler and Foam-Water Spray Systems — NFPA 16

NOTE 1: Foam systems may be used in areas where appreciable Class B hazards exist, especially where flammable liquid fuel in-depth or spills are likely.

NOTE 2: High-expansion foam systems are particularly suited for total flooding applications, but should not be used in normally occupied areas.

10-4.2

Foam systems shall be designed to be automatically actuated by an approved method of detection meeting the requirements of NFPA 72 and 72E.

10-4.3

Foam systems shall not be used to protect hazards involving energized electrical equipment.

10-5 Dry Chemical Systems.

10-5.1

Where appreciable Class B hazards exist, dry chemical systems shall be considered as appropriate protection.

NOTE 1: Dry chemical systems, utilizing multipurpose dry chemical, are also effective on Class A hazards, provided that “deep-seated” fires are not likely.

NOTE 2: Dry chemical systems may be used in conjunction with AFFF in a combined agent application, where securing action is required in addition to extinguishment.

NOTE 3: Electrical equipment need not be de-energized prior to system discharge, but shut-down is desirable if it can be accomplished.

NOTE 4: Dry chemical systems are not recommended for use in hazard areas where sensitive electrical equipment is located, due to the potential for damage to the equipment from the dry chemical and its products of decomposition where moisture and high temperatures are likely.

10-5.2

Where dry chemical systems are required by the fire hazard analysis, they shall be designed, installed, and maintained in accordance with the requirements of NFPA 17.

10-5.3

Dry chemical systems shall be designed to be automatically actuated by an approved method of detection meeting the requirements of NFPA 72 and 72E.

Chapter 11 Yard Mains and Hydrants

11-1

Outdoor fire hydrants and associated equipment shall be provided on the plant site for fire suppression undertaken by the plant fire brigade in the event of a major fire.

11-2

The yard mains shall be looped and shall be of sufficient size to meet the flow requirements specified in Section 12-4.

NOTE 1: Twelve-inch diameter cement-lined pipe is recommended. (*See NFPA 24, Standard for the Installation of Private Fire Service Mains and Their Appurtenances.*) Main sizes should be designed to encompass any anticipated expansion.

NOTE 2: The underground main should be arranged such that any one break will not put both a fixed water extinguishing system and hose lines protecting the same area out of service.

11-3

Sufficient indicator valves shall be installed to provide adequate sectional control of the fire water supply.

11-4

A sufficient number of hydrants shall be installed to provide two streams for every part of the interior of each building not covered by standpipe protection and to provide hose stream protection for every part of each building. There shall be sufficient hydrants to concentrate the required fire flow about any important structure with no hose line exceeding 500 ft (152 m) in length. Each hydrant shall have its own gate valve.

11-5

American National Fire Hose connection screw thread shall be specified. (*See NFPA 1963, Standard for Screw Threads and Gaskets for Fire Hose Connections.*)

11-5.1

Where threads of responding fire departments differ, adapters shall be provided at the hydrants.

Chapter 12 Water Supply

12-1

The water supply system for the permanent fire protection installation shall be determined by the fire hazard analysis.

12-2

A water supply shall be provided during the initial construction period as specified in 16-3(b).

12-3

The fire main system piping shall not serve service water system functions. The fire water loop shall meet the construction requirements of NFPA 24, *Standard for the Installation of Private Fire Service Mains and Their Appurtenances*.

12-4

The water supply for the permanent fire protection installation shall be based on the maximum automatic sprinkler or fixed water spray system demand, with simultaneous flow of 750 gpm at grade (2835 L/min) for hose streams and the shortest portion of the fire loop main out of service.

12-4.1

The use of multiple approved fire pumps shall be based on supplying the demand required in Section 12-4 with the largest pump out of service, utilizing different power sources.

12-4.2

Fire pumps shall meet the requirements of NFPA 20, *Standard for the Installation of Centrifugal Fire Pumps*, and shall be automatic starting.

12-5

An automatic pressure maintenance pump (jockey pump) or a head tank shall be provided to keep the fire water main pressure at approximately 10 psig (68.9 kPa) above the start pressure setting of the fire pump(s).

12-6

Pumps shall take suction from acceptable sources of water (*see NFPA 20*). If the source is from tanks, at least two tanks shall be provided and each tank shall be sized to contain a minimum 2-hour fire water flow demand. Where tanks are used, these tanks shall be automatically filled from a source capable of providing a 2-hour supply for the fire protection requirement in 8 hours. Fire water supply tanks shall comply with NFPA 22, including freeze protection requirements.

NOTE: The 8-hour requirement for refilling may be reduced or eliminated if the initial supply exceeds the 2-hour supply requirement on a volume/ratio basis.

12-7

Salt and tidal water shall not be acceptable primary natural water sources.

12-8

The following supervisory signals, where applicable, shall be received in the control room or plant security office in accordance with Chapter 9:

(a) Pump running

(b) Power failure

(c) Failure to start

(d) Water level

(e) Pump room and tank temperatures.

Chapter 13 Portable Fire Extinguishers and Hand Hose Lines

13-1 Portable and Wheeled Fire Extinguishers.

13-1.1

Portable and wheeled fire extinguishers shall be installed, inspected, maintained, and tested in accordance with NFPA 10 and approved or listed by a testing laboratory.

13-1.2

Portable and wheeled fire extinguishers shall be selected for the specific class or classes of hazards using the following descriptive guide.

13-1.2.1 Class “A” Hazards. Portable and wheeled fire extinguishers for protecting Class “A” hazards shall be selected from the following: water types, foam, Halon 1211, or multipurpose dry chemical.

NOTE 1: Portable and wheeled fire extinguishers that contain water, water/antifreeze, or foam should not be used on energized electrical equipment because a personal electrical shock hazard would be present.

NOTE 2: Multipurpose dry chemical is not recommended for installation in locations having sensitive electronic equipment, due to the potential for damage to this equipment from the dry chemical and its decomposition products.

13-1.2.2 Class “B” Hazards. Portable and wheeled fire extinguishers for protection of Class “B” hazards shall be selected from the following: dry chemical types, Halon 1211, foam, or carbon dioxide.

NOTE 1: In addition to its extinguishing capabilities, foam can be utilized to secure a flammable liquid spill before ignition.

NOTE 2: Some of the extinguishing agents, i.e., carbon dioxide and foam, are relatively ineffective on fires involving flammable liquids under pressure.

13-1.2.3 Class "C" Hazards. Portable and wheeled fire extinguishers for protecting Class "C" hazards shall be selected from the following: Halon 1211, carbon dioxide, dry chemical types.

NOTE 1: Carbon dioxide units equipped with metal horns should not be used on fires in energized electrical equipment.

NOTE 2: Dry chemical is not recommended for use in an area where sensitive electrical equipment is located, due to the potential for damage to this equipment from a dry chemical and its products of decomposition.

13-1.2.4 Class "D" Hazards. Portable and wheeled fire extinguishers and extinguishing agents for the protection of Class "D" hazards shall be of types approved for use on the specific combustible metal hazard.

NOTE 1: Where approvals are not available for a specific combustible metal, recommendations of a manufacturer may be utilized providing proper test data or use records are available.

NOTE 2: Agent for Class "D" hazards can be applied utilizing a scoop and a container.

13-1.3

A sign shall be located adjacent to each portable and wheeled fire extinguisher and shall plainly indicate the type of fire for which it is intended.

13-1.4

All persons working in an area shall be thoroughly trained in the use of all types of portable and wheeled fire extinguishers in the area and shall be familiar with their location. This training shall include both the capabilities and limitations of each available type of extinguisher.

13-2 Hand Hose Lines.

13-2.1

Hand hose lines utilizing water, foam, carbon dioxide, or dry chemical shall be installed, inspected, and maintained in accordance with the following NFPA standards, respectively: NFPA 14, NFPA 11, NFPA 12, and NFPA 17.

13-2.2

Hand hose lines utilizing water, foam, carbon dioxide, and dry chemical shall be selected for the specific class or classes of hazards utilizing the following descriptive guide.

13-2.2.1 Class "A" Hazards. Hand hose lines for the protection of Class "A" hazards shall be selected from the following: water, foam, and dry chemical (multipurpose only). The nozzles for these hand hose lines shall be approved, electrically safe nozzles in the plant areas where Class "A" hazards involve energized electrical equipment.

13-2.2.2 Class "B" Hazards. Hand hose lines for the protection of Class "B" hazards shall be selected from among the following: water, foam, and dry chemical.

NOTE: Foam is not considered suitable alone for fires involving gases and liquefied gases nor for three-dimensional flammable liquid fires. If these hazards are encountered, hand portable, wheeled dry chemical fire extinguishers or dry chemical hand hose lines are most effective especially when used in combination.

13-2.2.3 Class “C” Hazards. Hand hose lines for the protection of Class “C” hazards shall be selected from: water, carbon dioxide, and dry chemical. Approved nozzles shall be provided for use on Class “C” hazard fires.

13-2.2.3.1 The use of hand hose lines involving water or energized electrical equipment shall take into consideration:

(a) The voltage of the equipment.

(b) The type of water stream used, i.e., solid vs. spray.

(c) The effect of electrically conductive water on the operability of the equipment.

(d) The most probable distance between the fire fighter and the energized electrical equipment.

(e) The location of energized electrical equipment in the drainage path that is likely to be encountered when water is used.

13-2.2.3.2 Where sensitive electrical control equipment is involved, due consideration shall be given to the effects of thermal shock on the operability of this equipment when using carbon dioxide hand hose lines.

13-2.2.3.3 Carbon dioxide hand hose lines shall not be used in normally inhabited enclosures unless provisions for evacuation (alarm, annunciation, etc.) are made before use.

13-2.2.4 Class “D” Hazards. Hand hose lines involving water, foam, and carbon dioxide shall not be used for the protection of Class “D” hazards.

13-2.3

A sign shall be located adjacent to each hand hose station and shall plainly indicate the type of fire for which it is intended.

13-2.4

Designated persons working in the area shall be thoroughly trained in the inspection, location, and use of all hand hose line devices. This training shall include the capabilities and limitations for each type of hose station.

Chapter 14 Manual Fire Fighting

14-1

Manual fire fighting forces shall be available from:

(a) The plant fire brigade formed from the shift personnel.

(b) The public fire department from the nearest town.

NOTE: Due to the relatively remote location of most nuclear plants, such departments are usually a considerable distance away.

14-2 Action Plan.

Detailed action plans shall be worked out by the fire protection manager for proper deployment of in-plant fire fighting personnel. The plan shall require testing to verify its practicability and completeness by means of semiannual fire drills. Such drills shall be documented and kept on file at the plant for a minimum period of one year. The action plan shall consider the need for coordination between private and public fire fighting forces during drills and emergencies.

NOTE: Involvement of state and local agencies in semiannual drills is encouraged.

14-3 Standard for Fire Defense Measures.

All fire protection systems and devices such as automatic fixed fire extinguisher systems, automatic fire alarm and various layout arrangements, i.e., fire doors, fire dampers, ventilation arrangements, smoke venting, etc., shall be subjected to recurring and documented checks and tests. The staff shall be trained and drilled so that each person is capable of acting quickly and efficiently in the event of fire or danger of fire. A senior management representative, along with the fire protection manager, shall be responsible for ensuring that the plant fire defense is the best possible in all respects, including that all fire fighting equipment and systems are in working order. This supervisory activity shall be done by developing a plant emergency plan.

14-4 Liaison with Public Fire Authorities.

Liaison between and interfacing with the fire protection manager and the public fire authorities shall be maintained. It shall be the duty of the fire protection manager, together with the plant manager and plant security manager, in consultation with the public fire department, to make plans for fire fighting and rescue, including assistance from other organizations, and to maintain these plans in a current mode. Fire fighters from the public fire department and from other fire departments, including other industrial fire brigades that may be expected to respond to a fire at the plant, shall be familiarized with the plant layout. The access routes to fires in the controlled area (to which access doors are locked) shall be planned in detail in advance. The public fire department shall be given instructions and trained how to react in areas where radioactive materials, radiation, or hazardous materials may be present.

14-5 Regular Training and Drills.

Fire brigade members shall be given regular training and practice in fire fighting and rescue routines, including radioactivity and health physics considerations, to ensure that each member is thoroughly familiar with the steps to be taken in the event of fire, which will contribute to maintaining the best possible preparedness for such contingencies. Each fire brigade member shall be capable of acting:

(a) To alarm the plant fire brigade and public fire department.

(b) To identify any alarm zone or fire protection system that has operated.

(c) To use available rescue and extinguishing devices.

(d) To actuate the fixed fire extinguishing systems, the smoke venting systems, etc.

(e) To cooperate with and assist the public fire department in its work.

(f) To train plant personnel in room entry procedures where total flooding fire suppression systems are used. (*See NFPA 12, NFPA 12A, and NFPA 12B.*)

14-6 Equipment for the Plant Fire Brigade.

14-6.1

The conventional equipment (*see NFPA 600*) for the plant fire brigade shall be selected to suit the entire plant site. To complement the conventional equipment the following equipment shall be provided to cope with the nuclear hazard:

(a) Protective clothing.

(b) Respiratory protective equipment (*refer to NFPA 1981*).

(c) Radiation monitors.

(d) Personal dosimeters.

14-6.2

A formal program for the care and maintenance of the fire brigade equipment shall be established by the owner through the fire protection manager.

Chapter 15 Planning and Fire Protection

15-1

The owner or delegated fire protection manager shall be responsible for the entire fire protection of the plant site from conception and throughout the operating life of the plant. Fire protection shall be accorded the same consideration as nuclear hazards.

15-2

Fire protection shall be incorporated into the design specifications for the plant.

15-3

Fire protection measures shall keep pace with the advancement of the plant construction and corresponding fire hazards.

15-4

Special hazard fire protection shall be operational prior to the introduction of the hazard, such as energizing a transformer or filling oil tanks within the plant. Fire barriers and fire doors shall be given priority for construction and installation to reduce the spread of fire.

15-5 Repairs and Revision Work.

Special attention shall be paid to repairs and revision work outside of established areas. The requirement that written permission from the fire protection manager must be obtained before embarking on cutting, welding, use of other open flames in repairing fire protection systems, and similar operations shall be adopted. (*See NFPA 51B.*)

Chapter 16 Fire Prevention and Fire Protection for the Construction Site

16-1

Fire at the construction site shall not threaten the safety of the operating plant.

NOTE: Under construction and prior to the receipt of nuclear fuel, a nuclear power plant does not differ in any fundamental respect from a conventional steam generating plant or any other industrial plant of similar size with respect to fire protection problems. Due to large numbers of on-site personnel and high value materials, an above-average level of fire protection on the site is justified during erection of the plant. When a nuclear power plant is constructed in the vicinity of an existing plant, it is important that the exposure to the existing plant be taken into consideration.

16-2 Fire Prevention.

The owner or his designated fire protection manager shall be responsible for fire prevention of the entire plant site during the construction period. The duties shall be to:

(a) Develop, implement, and periodically update as necessary a fire procedure for the project and a fire brigade plan.

(b) Maintain housekeeping in such a manner so as to minimize the probability of fire causing loss of life or property damage.

(c) Provide periodic coordination with the public fire department and the plant fire brigade. (*See Chapter 14.*)

(d) Develop, implement, and periodically update as necessary an emergency evacuation plan for all personnel.

(e) Develop, implement, and periodically update as necessary a welding and cutting safety procedure using NFPA 51B and NFPA 241 as guides.

(f) Control the use of temporary buildings including trailers, shacks, or shanties within the confines of the plant.

(g) Specify the use of noncombustible scaffolds, form work, decking, and partitions both inside and outside permanent buildings.

(h) Establish a hazardous material control plan prohibiting the storage of flammable liquids, Class II combustible liquids, gases, or other hazardous material in permanent buildings. These materials shall be stored in a building at least 50 ft (15.2 m) from any permanent building and stored in accordance with NFPA 30. Flammable liquids and Class II combustible liquids shall be handled in listed containers in accordance with NFPA 30.

(i) Specify the use of approved tarpaulins.

(j) Develop, implement, and periodically update as necessary a fire prevention surveillance plan to include periodic recorded rounds to all unattended sections of the plant.

(k) Coordinate the initial and periodic testing of all systems and equipment affecting fire prevention and fire protection in accordance with the applicable NFPA standards and/or the manufacturers'/installers' instructions and procedures to include maintenance of appropriate documentation.

(l) Develop an alternate protection plan for those instances when it becomes necessary to remove any fire protection equipment or system from service.

(m) Specify labeled heating devices and their fuel supply systems for use inside or within 30 ft (9.1 m) of temporary and permanent buildings.

16-3 Fire Protection.

The owner or his designated fire protection manager shall be responsible for the provision of the following fire protection systems and/or equipment:

(a) *General Alarm System.* The system(s) shall be such that personnel on the site will be alerted.

(b) Minimum construction water supply shall be available on the site and capable of furnishing at least 750 gpm (2835 liters/min) plus the demand of the largest fixed water extinguishing system at a residual pressure of 75 psig (517 kPa) for minimum 2-hour duration.

(c) A temporary hydrant system with a maximum distance between any two hydrants of 250 ft (76.2 m). Hose and hydrant equipment shall be provided to assure an overlap of protection.

(d) A standpipe system in any permanent building that has as much as two-floor equivalent wall heights erected. Additional standpipe hose connections shall be added to each floor level as soon as sufficient landings are available to fight fires from that level. Protection from freezing shall be addressed.

(e) Fire extinguishers in accordance with NFPA 10.

(f) Automatic fire extinguishing system in any building or area of combustible construction or occupancy if there is a life safety hazard or large concentration of valuable equipment, the loss of which would cause an economic impact (i.e., delay in start-up dates) to the completed plant. Examples: Warehouses, offices, craft shops, etc.

16-4

Requirements for plants and areas under construction shall be determined by NFPA 241, *Safeguarding Building Construction and Demolition Operations*, and it is recognized that egress requirements may need to exceed those of completed facilities due to personnel, materials, and operations involved. The late stages of construction usually present the largest personnel concentration and highest hazard to personnel from fire in the life cycle of the plant.

Chapter 17 Life Safety

17-1

NFPA *101*, *Life Safety Code*, shall be the standard for life safety in the design and operation of nuclear power plants.

17-2*

The operation and maintenance of a nuclear power plant involves unique operation and material in process, due to which the majority of the areas involved in the transfer of nuclear energy to electrical energy shall be considered as either a special purpose industrial occupancy or as an occupancy in an unusual structure as defined in NFPA *101*. This determination shall be made in the conceptual fire hazard analysis.

NOTE: These classifications consider that several areas will not normally be subject to human occupancy and that radioactive material is involved.

Chapter 18 Referenced Publications

18-1

The following documents or portions thereof are referenced within this standard and shall be considered part of the requirements of this document. The edition indicated for each reference is the current edition as of the date of the NFPA issuance of this document.

18-1.1 NFPA Publications.

National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.

NFPA 10, *Standard for Portable Fire Extinguishers*, 1990 edition

NFPA 11, *Standard for Low Expansion Foam and Combined Agent Systems*, 1988 edition

NFPA 11A, *Standard for Medium- and High-Expansion Foam Systems*, 1988 edition

NFPA 12, *Standard on Carbon Dioxide Extinguishing Systems*, 1993 edition

NFPA 12A, *Standard on Halon 1301 Fire Extinguishing Systems*, 1992 edition

NFPA 12B, *Standard on Halon 1211 Fire Extinguishing Systems*, 1990 edition

NFPA 13, *Standard for the Installation of Sprinkler Systems*, 1991 edition

NFPA 14, *Standard for the Installation of Standpipe and Hose Systems*, 1993 edition

NFPA 15, *Standard for Water Spray Fixed Systems for Fire Protection*, 1990 edition

NFPA 16, *Standard on the Installation of Deluge Foam-Water Sprinkler and Foam-Water Spray Systems*, 1991 edition

NFPA 17, *Standard for Dry Chemical Extinguishing Systems*, 1990 edition

NFPA 20, *Standard for the Installation of Centrifugal Fire Pumps*, 1990 edition

NFPA 22, *Standard for Water Tanks for Private Fire Protection*, 1993 edition

NFPA 24, *Standard for the Installation of Private Fire Service Mains and Their Appurtenances*, 1992 edition

NFPA 30, *Flammable and Combustible Liquids Code*, 1990 edition

NFPA 31, *Standard for the Installation of Oil-Burning Equipment*, 1992 edition

NFPA 37, *Standard for the Installation and Use of Stationary Combustion Engines and Gas Turbines*, 1990 edition

NFPA 50A, *Standard for Gaseous Hydrogen Systems at Consumer Sites*, 1989 edition

NFPA 51B, *Standard for Fire Prevention in Use of Cutting and Welding Processes*, 1989 edition

NFPA 70, *National Electrical Code*, 1993 edition

NFPA 71, *Standard for the Installation, Maintenance, and Use of Signaling Systems for Central Station Service*, 1989 edition

NFPA 72, *Standard for the Installation, Maintenance, and Use of Protective Signaling Systems*, 1990 edition

NFPA 72E, *Standard on Automatic Fire Detectors*, 1990 edition

NFPA 80, *Standard for Fire Doors and Fire Windows*, 1992 edition

NFPA 80A, *Recommended Practice for Protection of Buildings from Exterior Fire Exposures*, 1993 edition

NFPA 85C, *Standard for Prevention of Furnace Explosions/Implosions in Multiple Burner*

Boiler-Furnaces, 1991 edition

NFPA 90A, *Standard for the Installation of Air Conditioning and Ventilating Systems*, 1993 edition

NFPA 91, *Standard for Exhaust Systems for Air Conveying of Materials*, 1992 edition

NFPA *101*, *Life Safety Code*, 1991 edition

NFPA 204M, *Guide for Smoke and Heat Venting*, 1991 edition

NFPA 214, *Standard on Water-Cooling Towers*, 1992 edition

NFPA 220, *Standard on Types of Building Construction*, 1992 edition

NFPA 241, *Standard for Safeguarding Construction, Alteration, and Demolition Operations*, 1989 edition

NFPA 251, *Standard Methods of Fire Tests of Building Construction and Materials*, 1990 edition

NFPA 252, *Standard Methods of Fire Tests of Door Assemblies*, 1990 edition

NFPA 255, *Standard Method of Test of Surface Burning Characteristics of Building Materials*, 1990 edition

NFPA 256, *Standard Methods of Fire Tests of Roof Coverings*, 1993 edition

NFPA 600, *Standard on Industrial Fire Brigades*, 1992 edition

NFPA 780, *Lightning Protection Code*, 1992 edition

NFPA 1963, *Standard for Screw Threads and Gaskets for Fire Hose Connections*, 1985 edition

NFPA 1981, *Standard on Open-Circuit Self-Contained Breathing Apparatus for Fire Fighters*, 1992 edition

NFPA 8501, *Standard for Single Burner Boiler Operation*, 1992 edition

18-1.2 Other Publications.

18-1.2.1 ANSI Publications. American National Standards Institute, 1430 Broadway, New York, NY 10018.

ANSI B31.1 (1986), *Power Piping*

ANSI B31.7 (1969), *Nuclear Power Piping (Addenda B31.7a-1972, B31.7b-1971, B31.7c-1971)*

18-1.2.2 ASTM Publication. American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103.

ASTM E136-1982, *Test for Behavior of Materials in a Vertical Tube Furnace at 750°C*

18-1.2.3 IEEE Publication. Institute of Electrical and Electronics Engineers, 345 East 47th Street, New York, NY 10017.

IEEE 383-1974 (R-1980) Standard for Type Test of Class IE Electric Cables, *Field Splices and Connections for Nuclear Power Generating Stations*

18-1.2.4 UL Publication. Underwriters Laboratories Inc. 333 Pfingsten Road, Northbrook, IL 60062.

UL 586-1977, *Test Performance of High Efficiency, Particulate, Air-Filter Units*

Appendix A

This Appendix is not a part of the requirements of this NFPA document, but is included for information purposes only.

A-1-1

There is information contained within this standard that is applicable to reactors other than light water reactors. Principles outlined in this standard are also applicable to nuclear production reactors. Applicable guidance for design and protection of production and research reactors may be found in this standard.

A-2-4 Fire Hazard Analysis.

A thorough analysis of the fire potential is necessary to incorporate adequate fire protection into the facility design. Integrated design of systems is necessary to ensure the safety of the plant and the operators from the hazards of fire and to protect property and continuity of production.

The following steps are recommended as part of the analysis procedure.

(1) Prepare a general description of the physical characteristics of the power facilities and plant location which will outline the "fire prevention" and "fire protection" systems to be provided. Define the fire hazards that can exist and state the loss limiting criteria to be used in the design of the plant.

(2) List the codes and standards that will be used for the design of the fire protection systems. Include the published standards of the National Fire Protection Association. Select the specific sections and paragraphs, not general items.

(3) Define and describe the potential fire characteristics for all individual plant areas which have combustible materials, such as: maximum fire loading, hazards of flame spread, smoke generation, toxic contaminants, and fuel contributed. Consider the use and effect of noncombustible and heat-resistant materials.

(4) List the fire protection system requirements and the criteria to be used in the basic design for such items as water supply, water distribution systems, and fire pump safety.

(5) Describe the performance requirements for the detection systems, alarm systems, automatic suppression systems, manual systems, chemical systems, and gas systems for fire detection, confinement, control, and extinguishing.

(6) Develop the design considerations for suppression systems and for smoke, heat, and flame control, combustible and explosive gas control, toxic and contaminate control. Select the operating functions of the ventilating and exhaust systems during the period of fire extinguishing and control. List the performance requirements for fire and trouble annunciator warning system and the auditing and reporting systems.

(7) Consider the qualifications required for the personnel performing the inspection checks and the frequency of testing to maintain a reliable alarm detection system.

(8) The features of building and facility arrangements and the structural design features generally define the methods for fire prevention, fire extinguishing, fire control, and control of hazards created by fire. Fire barriers, egress, fire walls, and the isolation and containment features that should be provided for flame, heat, hot gases, smoke, and other contaminants

should be carefully planned. Outline the drawings and list of equipment and devices which are needed to define the principal and auxiliary fire protection systems.

(9) Prepare a list of the dangerous and hazardous combustibles and the maximum amounts estimated to be present in the facility. Evaluate where these will be located in the facility.

(10) Review the types of fires, based on the quantities of combustible materials, their estimated severity, intensity, duration, and the hazards created. Indicate for each of the types reviewed the total time involved, and the time for each step from the first alert of the fire hazard until safe control and extinguishment is accomplished. Describe in detail the plant systems, functions, and controls that will be provided and maintained during the fire emergency.

(11) Define the essential electric circuit integrity needed during fire. Evaluate the electrical and cable fire protection, the fire confinement control, and extinguishing systems that will be required to maintain their integrity.

(12) Carefully review and describe the control and operating room areas and the protection and extinguishing systems provided thereto. Do not overlook the extra facilities provided for maintenance and operating personnel, such as kitchens, maintenance storage, and supply cabinets.

(13) Consider the fire hazards and potentials during construction of multiple units and the additional fire prevention and control provisions that will be required during the construction period where one unit is in operation. This may require additional professional fire department type of coverage.

(14) Analyze what is available in the form of “back-up” or “public” fire protection to be considered for the installation. Review the “back-up” fire department, equipment, manpower, special skills, and training required.

(15) List and describe the installation, testing, and inspection required during construction of the fire protection systems which demonstrate the integrity of the systems as installed. Evaluate the operational checks, inspection, and servicing required to maintain this integrity.

(16) Evaluate the program for training, updating, and maintaining competence of the station fire fighting and operating crew. Provisions should be required to maintain and upgrade the fire fighting equipment and apparatus during plant operation.

(17) Review the qualification requirements for the fire protection engineer or consultant who will assist in the design and selection of equipment. This person will also inspect and test the completed physical aspects of the system and develop the complete fire protection program for the operating plant.

A-7-3.1.1 The varying radiation dose rates found in different parts of a nuclear power plant and caused by airborne radioactive substances, radiation from plant systems, and radiation from contaminated surfaces are the reason for the subdivision of the plant premises into what are sometimes called controlled and uncontrolled areas in order to limit the exposure of the employees when working in different parts of the plant. This classification applies to normal operating conditions. The dose rates may change substantially in the event of a serious accident. The division of the premises into controlled and uncontrolled areas also affects the dividing into fire protection areas, the design of ventilation systems, and requirements concerning surface treatment of ceilings, walls, floors, etc. (International Guidelines for Fire Protection for Nuclear Power Plants).

The presence of gaseous or airborne radioactive substances imposes certain requirements on the pressure differentials and direction of the pressure gradient between adjoining rooms and within the ventilation systems of the plant. The radioactive substances must be kept under control by always maintaining the flow of air from the less towards the more contaminated rooms and regions. The usual way of smoke detection may therefore not always be applicable.

Depending on the type of reactor, the space, compartments, and adjoining rooms where the components of the primary reactor coolant circuit are installed may be used for emergency pressure relief in case of a rupture in the primary coolant circuit. Parts of the entire volume of the reactor building, or the containment, may be used in order to attain an acceptable equalized relief pressure. The required interconnections of the different compartments of the reactor building contradict the normal fire protection practice of subdividing large spaces into smaller isolated compartments for confinement of the damage by smoke and heat (International Guidelines for Fire Protection for Nuclear Power Plants).

A-10-1.5

On wet pipe sprinkler systems, alarm check valves are preferred.

A-10-1.6

Electric valve supervision is preferred. This method of valve supervision indicates to the operator the status of fire protection control valves at any given instant. Locks or seals do not assure that valves are open or closed.

A-17-2

In most fire and fire related incidents the primary duty of plant personnel should be to retain the integrity of systems designed for safe operation and shut down of nuclear facilities and containment of radioactive release. Provisions should be made that personnel can carry out this function in as safe a manner as possible with adequate means of egress and access to all areas of the plant.

Normal operation may involve relatively few personnel; however, certain activities, such as maintenance, testing, and start-up may involve a great number of occupants not necessarily familiar with plant layout and means of egress in emergency situations. Nuclear power plant design utilizes methods such as air locks and pressure differentials to segregate plant areas. These methods require full evaluation to assure the availability of means of egress and access in emergency situations.

In evaluating the exits for a completed facility, the number of personnel and occupancy hazard during maintenance, refueling, and testing should determine the exit requirements if greater potential for fire exists under these conditions.

Appendix B Codes and Standards

This Appendix is not a part of the requirements of this NFPA document, but is included for information purposes only.

General. There are a number of publications relating to fire protection features of nuclear reactors, particularly power reactors. In terms of content, these can be grouped into two classes: those dealing with the property protection features of the plant as a whole, and those concerned with fire protection features affecting public safety or the protection of systems essential to nuclear safety of the reactor.

Regulatory Guides. Although none of these publications is mandatory, the Nuclear Regulatory Commission must be satisfied that effective fire protection is provided before an operating license is issued. This may be done by strict adherence to the guide or by proving that alternates will accomplish the job. However, the NRC guides are concerned with nuclear safety and protection of the public, with little direct application to the safety of employees and/or construction workers, to property protection of the plant as a whole, or to the continuity of power production. The purpose of a regulatory guide is, in its own words, to "make available specific parts of the Commission regulations, to delineate techniques used by the staff in evaluating specific problems or postulated accidents, or to provide guidance to applicants. Regulatory guides are not substitutes for regulations, and compliance with them is not required. Methods and solutions different from those set out in the guides will be acceptable if they provide a basis for the findings requisite to the issuance or continuance of a permit or license by the Commission."

Applicable Guides. Guides relating to the fire protection of nuclear reactors are described below.

Regulatory Guide 1.120 — Fire Protection Guidelines for Nuclear Power Plants. This was issued by the NRC for comment, but has not been finalized. It contains most of the provisions described in the Standard Review Plan.

Standard Review Plan 9.5.1 — Fire Protection System. NUREG 800 is the basic NRC document delineating their review procedures for nuclear power plant applications. Section 9.5.1 covers fire protection. While intended for the regulatory staff of NRC as guidance for review procedures, it serves as a useful planning guide to applicants. The current edition is the July 1981 revision.

Branch Technical Position APCSB 9.5-1. Guidelines for Fire Protection for Nuclear Power Plants. These guidelines are prepared by the branches having standards-making responsibilities for the subject in question, in this case the Auxiliary Power and Control Code of Federal Regulations 10 CFF Part 50, Appendix R — Fire Protection Program for Nuclear Power Facilities operating prior to January 1, 1979. These are the basic, mandatory requirements of the NRC applicable to the defined facilities. The general requirement for the fire protection and prevention programs are contained herein, as well as specific requirements for fire brigades, water supplies, safe shutdown capability protection, fire barrier seals, and other subjects. The Federal Register, Vol. 45, No. 105, of May 29, 1980, printed the Appendix, together with an analysis of the requirements and an excellent background discussion of the various NRC requirements and guides.

International Atomic Energy Authority (IAEA) Safety Guide on Fire Protection in Nuclear Power Plants. This document is currently being drafted to "provide specific guidance for the designer and the operating staff in complying with requirements for protection of systems important to nuclear safety." IAFA guides are useful references but are not mandatory in the U.S.

American Nuclear Insurers-Mutual Atomic Energy Reinsurance Pool and Nuclear Mutual Limited Standards. Each of these insurance pools issues standards covering the fire protection of the entire nuclear power plant. Substantial compliance is required for all plants insured within the pools. The scope of these requirements is broader than the above documents but life safety aspects for employees and construction workers are not a specific concern.

International Guidelines for the Fire Protection of Nuclear Power Plants. This is a comprehensive document published on behalf of the national nuclear risks insurance pools and associations. This is the broadest-scope document in print, covering protection features for the entire plant. Again, this is primarily property protection oriented, but is basically compatible with the U.S. insurance pools requirements and is a consensus document of the insurance pools involved.

NFPA 804

1995 Edition

Standard for Fire Protection for Advanced Light Water Reactor

Electric Generating Plants

1995 Edition

This edition of NFPA 804, *Standard for Fire Protection for Advanced Light Water Reactor Electric Generating Plants*, was prepared by the Technical Committee on Atomic Energy and acted on by the National Fire Protection Association, Inc., at its Annual Meeting held May 22-25, 1995, in Denver, CO. It was issued by the Standards Council on July 21, 1995, with an effective date of August 11, 1995.

This edition of NFPA 804 was approved as an American National Standard on August 11, 1995.

Origin and Development of NFPA 804

The need for fire protection in nuclear power facilities has been demonstrated in a number of incidents, including the Browns Ferry Fire in 1975 and other more recent incidents in the United States and abroad. Probabilistic risk assessments of existing plants have shown that fire represents one of the largest single contributors to the possibility of reactor damage. This document represents a comprehensive consensus of baseline fire protection requirements for all aspects of advanced lightwater reactor electric generating plants including the design, construction, operation, and maintenance.

Technical Committee on Atomic Energy

Walter W. Maybee, *Chair*
Los Alamos Nat'l Laboratories, NM

Wayne D. Holmes, *Secretary*
HSB Professional Loss Control Inc., PA

Mario A. Antonetti, Gage-Babcock & Assn. Inc., NY

William G. Boyce, U.S. Dept. of Energy, DC

Harry M. Corson, IV, Cerberus Pyrotronics, NJ
Rep. Nat'l Electrical Mfrs. Assn.

Donald A. Diehl, Alison Control Inc., NJ

Paul H. Dobson, Factory Mutual Research Corp., MA

Stewart M. Fastman, American Ins Services Group Inc., NY

Paul Giaccaglia, American Nuclear Insurers, CT

Arie T. P. Go, Bechtel Corp., CA

Leonard R. Hathaway, M & M Protection Consultants, IL

LeRoy J. Hill, McDermott Inc., VA

L. S. Homa, Underwriters Laboratories Inc., IL

Jacob B. Klevan, Rolf Jensen & Assoc. Inc., VA

Thomas J. Kramer, Schirmer Engineering Corp., IL

Robert S. Levine, U.S. Nat'l Inst. of Standards and Technology, MD

Patrick M. Madden, U.S. Nuclear Regulatory Commission, DC

Anthony J. Mascena, Stone & Webster Engineering Corp., NJ

Brian J. Meacham, FireTech, Switzerland

David P. Notley, Science Applications Int'l. Corp. (SAIC), VA

Robert J. O'Laughlin, Knoxville, TN

Chandrakant A. Oza, General Electric Co., CA

Mark Henry Salley, Tennessee Valley Authority, TN

Jack Siegel, Raytheon Engrs & Constructors, NY

Clifford R. Sinopoli, II, Baltimore Gas & Electric, MD
Rep. Electric Light Power Group/Edison Electric Inst.

Wayne R. Sohlman, Nuclear Mutual Ltd, DE

Rupert M. H. Terrier, Virginia Electric & Power Co., VA

Lynn K. Underwood, Wausau Insurance Cos., WI
Rep. The Alliance of American Insurers

Steven F. Vieira, Grinnell Corp., RI
Rep. Nat'l Fire Sprinkler Assn.

Michael J. Vitacco, Jr., Westinghouse Savannah River Co., SC

Alternates

Daniel L. Arnold, Rolf Jensen & Assoc., GA
(Alt. to J. B. Klevan)

Ingemar B. Asp, Gage Babcock & Assn. Inc., NY
(Alt. to M. A. Antonetti)

James B. Biggins, M & M Protection Consultants, IL
(Alt. to L. R. Hathaway)

Warren D. Bonisch, Schirmer Engineering Corp., VA
(Alt. to T. J. Kramer)

Edward A. Connell, U.S. Nuclear Regulatory Commission, DC
(Alt. to P. M. Madden)

Dennis Eaves, American Nuclear Insurers, CT
(Alt. to P. Giaccaglia)

L. Paul Herman, Professional Loss Control, Inc., IL
(Alt. to W. D. Holmes)

Neal W. Krantz, Simplex, MI
(Alt. to H. M. Corson, IV)

Jimmy J. Pierce, Tennessee Valley Authority, TN
(Alt. to M. H. Salley)

Thomas A. Storey, Science Applications Int'l. Corp. (SAIC), VA
(Alt. to D. P. Notley)

James R. Streit, Westinghouse Savannah River Co., SC
(Alt. to M. J. Vitacco, Jr.)

Robert W. Strong, General Electric, CA
(Alt. to C. A. Oza)

Brian D. Tomes, Wausau Insurance Cos., TX
(Alt. to L. K. Underwood)

Nonvoting

Donald J. Keigher, Los Alamos, NM
(Member Emeritus)

Casey C. Grant, NFPA Staff Liaison

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NOTE: Membership on a Committee shall not in and of itself constitute an endorsement of the Association or any document developed by the Committee on which the member serves.

Committee Scope: This Committee shall have primary responsibility for documents on the safeguarding of life and property from fires in which radiation or other effects of nuclear energy might be a factor.

NFPA 804

Standard for Fire Protection for Advanced Light Water Reactor Electric Generating Plants

1995 Edition

NOTICE: An asterisk (*) following the number or letter designating a paragraph indicates explanatory material on that paragraph in Appendix A.
Information on referenced publications can be found in Chapter 10 and Appendix B.

Chapter 1 Introduction

1-1* Scope.

This standard applies only to advanced light water reactor electric generating plants, and provides minimum fire protection requirements to ensure safe shutdown of the reactor, minimize the release of radioactive materials to the environment, provide safety to life of on-site personnel, limit property damage, and protect continuity of plant operation. The fire protection is based upon the principle of defense in depth.

1-2 Purpose.

This standard is prepared for the use and guidance of those charged with the design, construction, operation, and regulation of advanced light water reactor electric generating plants. This standard covers those requirements essential to ensure that the consequences of fire will have minimum impact on the safety of the public and on-site personnel, the physical integrity of plant components, and the continuity of plant operations.

1-3 Equivalency Concepts.

1-3.1

Nothing in this standard is intended to prevent the use of systems, methods, or devices of equivalent or superior quality, strength, fire resistance, effectiveness, durability, and safety as alternatives to those prescribed by this standard, provided technical documentation is submitted to the authority having jurisdiction to demonstrate equivalency, and the system, method, or device is approved for the intended purpose.

1-3.2

The specific requirements of this standard shall be permitted to be modified by the authority having jurisdiction to allow alternative arrangements that will secure as nearly as practical the level of fire protection intended by this document, but in no case shall the modification afford less fire protection than that which, in the judgment of the authority having jurisdiction, would be provided by compliance with the corresponding provisions contained in this standard.

1-3.3

Alternative fire protection methods accepted by the authority having jurisdiction shall be considered as conforming with this standard.

1-4 Definitions.

Advanced Light Water Reactors (ALWR).* Advanced light water reactors are divided into two types:

(a) *Evolutionary Plants.* These are simpler, improved versions of conventional designs employing active safety systems.

(b) *Revolutionary Plants.* These are the result of completely rethinking the design philosophy of conventional plants. Revolutionary plants currently being proposed replace mechanical safe shutdown systems with passive features that rely on physical properties such as natural circulation, gravity flow, and heat sink capabilities.

Alternative Shutdown Capability. The ability to safely shut down the reactor and maintain shutdown using equipment and processes outside the normal reactor shutdown process.

ALWR. See Advanced Light Water Reactors.

Approved.* Acceptable to the authority having jurisdiction.

Associated Circuits of Concern. Those safety-related and non-safety-related circuits not directly required to perform a safe shutdown function that have a physical separation from the fire area less than that required by Section 5-4 and that have any of the following characteristics:

(a) *Type I.* A common power source with a required circuit in which the power source is not electrically protected from the nonrequired circuit by coordinated circuit breakers, fuses, or similar devices.

(b) *Type II.* A connection to equipment whose spurious operation could adversely affect safe shutdown capability.

(c) *Type III.* A common enclosure (e.g., cable tray, conduit, panel, or junction box) with a required circuit and that:

1. Is not electrically protected by circuit breakers, fuses, or similar devices, or

2. Could allow propagation of fire into the common enclosure.

A potential Type I or Type III circuit is not an associated circuit of concern if it has adequate electrical protection.

Authority Having Jurisdiction.* The organization, office, or individual responsible for approving equipment, an installation, or a procedure.

Cable Tray Fire Break. A noncombustible or limited-combustible material used for vertical cable trays to limit fire spread.

Cold Shutdown. A stable plant condition in which the affected reactor is subcritical and the average reactor coolant system temperature is less than or equal to 200°F (93°C).

Combustible. Any material that, in the form in which it is used and under the conditions anticipated, will ignite and burn. A material that does not meet the definition of noncombustible or limited-combustible.

Combustible Liquid. A liquid having a flash point at or above 100°F (37.8°C). (*See NFPA 30, Flammable and Combustible Liquids Code*.)

Defense in Depth. A principle aimed at providing a high degree of fire protection by achieving a balance of:

(a) Preventing fires from starting;

(b) Detecting fires quickly and suppressing those fires that occur, thereby limiting damage; and

(c) Designing the plant to limit the consequences of fire to life, property, environment, continuity of plant operation, and safe shutdown capability.

It is recognized that, independently, no one of these items is complete in itself. Strengthening any item can compensate for weaknesses, known or unknown, in the other items.

FHA. See Fire Hazards Analysis.

Fire Area.* That portion of a building or plant that is separated from other areas by boundary fire barriers.

Fire Area Subdivision.* A portion of a fire area separated from the remainder of the fire area by substantive barriers (not necessarily fire rated) or by plant physical features, such as pipe tunnels, or by spatial separation.

Fire Barrier. A continuous membrane, either vertical or horizontal, such as a wall or floor assembly, that is designed and constructed with a specified fire resistance rating to limit the spread of fire and that will also restrict the movement of smoke. Such barriers shall be permitted to have protected openings.

Fire Brigade.* As used in this standard, refers to those on-site persons trained in plant fire-fighting operations.

Fire Door. A door assembly rated in accordance with NFPA 252, *Standard Methods of Fire Tests of Door Assemblies*, and installed in accordance with NFPA 80, *Standard for Fire Doors and Fire Windows*.

Fire Hazards Analysis (FHA). An analysis performed by fire protection and reactor systems engineers to evaluate potential in situ and transient fire hazards to determine the effect of fire in any location in the plant on the ability to shut down the reactor safely and minimize and control the release of radioactive materials to the environment; and to specify measures for fire protection.

Fire Prevention. Measures directed toward avoiding the inception of fire.

Fire Protection. Methods of providing fire detection, control, and extinguishment.

Fire Protection Manager. The person directly responsible for the fire prevention and fire protection program at the plant.

Fire-Rated Cables.* Cables with an hourly fire resistance rating based on maintaining functionality when exposed to fire tests in NFPA 251, *Standard Methods of Tests of Fire Endurance of Building Construction and Materials*.

Fire-Rated Internal Conduit Seal. A conduit seal that is a tested and approved hourly rated fire seal in accordance with ASTM E 814, *Fire Tests of Through-Penetration of Fire Stops*.

Fire-Rated Penetration Seal. An assembly provided in an opening in a fire barrier for the passage of pipes, cable trays, etc., to maintain the fire resistance rating of the fire barrier.

Fire Resistance Rating. The time, in minutes or hours, that materials or assemblies have withstood a fire exposure as established in accordance with an approved test procedure appropriate for the component under consideration.

Fire Safe Shutdown. Actions, components, capabilities, and design features necessary to achieve and maintain safe shutdown of the reactor after a fire in a specific fire area.

Fire Safe Shutdown Component. Equipment, instrument sensing lines, or cables (including associated circuits of concern) that are required to safely shut down the plant in the event of fire. Fire safe shutdown components might or might not be nuclear safety related.

Fire Zone. Areas in which fire detection or suppression systems provide alarm information indicating the location of fire at a central fire control center.

First Break. The first place in a conduit run where the interior of the conduit is accessible to install a seal. The first break could be a condulet, a pull box, a junction box, or an electrical panel, at the equipment or open ended with cables exiting into a tray.

Flame Spread Rating. A relative measurement of the surface burning characteristics of building materials when tested in accordance with NFPA 255, *Standard Method of Test of Surface Burning Characteristics of Building Materials*.

Flammable Liquid. Any liquid having a flash point below 100°F (37.8°C) and having a vapor pressure not exceeding 40 psi (276 kPa) absolute pressure at 100°F (37.8°C).

Free of Fire Damage. The necessary structures, systems, and components are free of fire damage if the structure, system, or component under consideration is capable of performing its intended function during and after a fire.

FSSD. See Fire Safe Shutdown.

High Impedance Faults. Fire-induced faults on non-safe shutdown essential circuits routed thorough a common fire area that are assumed to occur simultaneously and have a current magnitude below the trip point for the individual circuits. The sum of the currents generated by the simultaneous occurrence of such faults could trip the main circuit breaker and cause the loss of a safe shutdown power supply.

High-Low Pressure Interface. A valve or set of valves that separates a high pressure primary coolant system from a low pressure system. Fire induced faults on the valve(s) circuitry can cause (a) loss of the ability to close the valve(s), or (b) spurious opening of the valve(s), thereby inducing a loss of coolant accident (LOCA) or overpressurizing the low pressure system.

Labeled. Equipment or materials to which has been attached a label, symbol, or other identifying mark of an organization that is acceptable to the authority having jurisdiction and concerned with product evaluation that maintains periodic inspection of production of labeled equipment or materials and by whose labeling the manufacturer indicates compliance with appropriate standards or performance in a specified manner.

Limited-Combustible. A building construction material that, in the form in which it is used, has a potential heat value not exceeding 3500 Btu/lb (8141 kJ/kg) and either has a structural base of noncombustible material with a surfacing not exceeding $^{1}/_{8}$ in. (3.2 mm) that has a flame spread rating not greater than 50, or other material having neither a flame spread rating greater than 25 nor evidence of continued progressive combustion, even on surfaces exposed by cutting through the material on any plane. (*See NFPA 220, Standard on Types of Building Construction*.)

Listed.* Equipment or materials included in a list published by an organization acceptable to the authority having jurisdiction and concerned with product evaluation that maintains periodic inspection of production of listed equipment or materials and whose listing states either that the equipment or material meets appropriate standards or has been tested and found suitable for use in a specified manner.

Noncombustible. A material that, in the form in which it is used and under the conditions anticipated, will not ignite, burn, support combustion, or release flammable vapors when subjected to fire or heat. Materials that are reported as passing ASTM E 136, *Standard Test Method for Behavior of Materials in a Vertical Tube Furnace at 750°C*, shall be considered noncombustible.

Normal Operations. All modes of plant operation, ranging from 0 percent to 100 percent power, including refueling outages but not including extended outages when fuel is removed from the reactor.

Nuclear Safety Function. Any function that is necessary to ensure the integrity of the reactor coolant pressure boundary; the capability to shut down the reactor and maintain it in a safe shutdown condition; or the capability to prevent or mitigate the consequences of plant conditions that could result in potential off-site exposures that are a significant fraction of Title 10, *Code of Federal Regulations*, Part 100, “Reactor Site Criteria,” guideline exposures.

Nuclear Safety Related. Structures, systems, or components that, as defined by Title 10, *Code of Federal Regulations*, Part 100, “Reactor Site Criteria,” are required to remain functional to ensure:

(a) The integrity of the reactor coolant pressure boundary,

(b) The capability to shut down the reactor and maintain it in a safe shutdown condition, or

(c) The capability to prevent or mitigate the consequences of accidents that could result in potential off- site exposures comparable to the guideline exposures of 10 CFR 100.

Postulated Fire. A fire that is assumed to occur in a specific area of the plant. The origin of the fire and the combustible materials involved are not defined.

Power Block. Those structures having equipment required for plant operations (e.g., containment, auxiliary building, service building, control building, fuel building, rad waste, water treatment, turbine building, and intake structure).

Redundant Component, System, or Subsystem. A component, system, or subsystem that independently duplicates the essential function of another component, system, or subsystem.

Safe Shutdown. A shutdown with the reactivity of the reactor kept subcritical as specified by the technical specifications for the unit.

Safety Division. The designation applied to a given system or set of nuclear-safety-related components that enable the establishment and maintenance of physical, electrical, and functional independence from other redundant systems or sets of components. The terms division, train, and separation group, when used in this context, are interchangeable.

Shall. Indicates a mandatory requirement.

Should. Indicates a recommendation or that which is advised but not required.

Spurious Operation. An unwanted change in state of equipment due to fire-induced faults (hot shorts, open circuits, or shorts to ground) on its power or control circuitry. Spurious operations include, but are not limited to:

(a) The opening (closing) of normally closed (open) valves,

(b) Starting (stopping) of pumps or motors,

(c) Actuation of logic circuits, or

(d) Inaccurate instrument reading.

Spurious Signal. A fire-induced signal that could cause the spurious operation of components or equipment, which would adversely affect the safe shutdown capability.

Chapter 2 Fire Protection Program

2-1 General.

2-1.1

This chapter establishes the criteria for an integrated combination of components, procedures, and personnel to carry out all activities involved in the fire protection program. It includes system and facility design, fire prevention, fire detection, notification, confinement, suppression, administrative controls, fire brigade organization, inspection and maintenance, training, quality assurance, and testing.

2-1.2

All elements of the site fire protection program shall be reviewed every two years, and updated as necessary.

Exception: Other review frequencies are acceptable where specified in site administrative procedures and approved by the authority having jurisdiction.

2-1.3

The intent of this chapter can be met by incorporating the features of this chapter in the safety analysis reports, operating procedures, program manual, policy documents, and other verifiable records as plant management determines.

2-2 Management Policy Direction and Responsibility.

2-2.1

A policy document shall be prepared that defines management authorities and responsibilities and establishes the general policy for the site fire protection program.

2-2.2

The policy document shall designate the senior management person with immediate authority and responsibility for the fire protection program.

2-2.3

The policy document shall define the fire protection interfaces with other organizations and assign responsibilities for the coordination activities.

2-2.4

The policy document shall include the authority for conflict resolution.

2-3 Fire Prevention Program.

A fire prevention program shall be established and documented to include:

(a) Fire safety information for all employees and contractors, including as a minimum familiarization with plant fire prevention procedures, fire reporting, and plant emergency alarms, including evacuation;

(b) Documented plant inspections including provisions for handling of remedial actions to correct conditions that increase fire hazards;

(c) A procedure for the control of general housekeeping practices and the control of transient combustibles;

(d) Procedures for the control of flammable and combustible gases in accordance with NFPA standards;

(e) Procedures for the control of ignition sources, such as smoking, welding, cutting, and grinding (*see NFPA 51B, Standard for Fire Prevention in Use of Cutting and Welding Processes*);

(f) A fire prevention surveillance plan (*see NFPA 601, Standard on Guard Service in Fire Loss Prevention*); and

(g) A fire reporting procedure, including investigation requirements and corrective action requirements.

2-4* Fire Hazards Analysis.

A documented fire hazards analysis shall be made for each site. The analysis shall document:

(a) The physical construction and layout of the buildings and equipment, including fire areas and the fire ratings of area boundaries;

(b)* An inventory of the principal combustibles within each fire subdivision;

(c) A description of the fire protection equipment, including alarm systems and manual and automatic extinguishing systems;

(d) A description of any equipment necessary to ensure a safe shutdown, including cabling and piping between equipment, and the location of such equipment;

(e) An analysis of the postulated fire in each fire area, including its effect on safe shutdown equipment, assuming automatic and manual fire protection equipment does not function;

(f) An analysis of the potential effects of a fire on life safety, release of contamination, impairment of operations, and property loss, assuming the operation of installed fire extinguishing equipment;

(g) An analysis of the potential effects of other hazards, such as earthquakes, storms, and floods, on fire protection;

(h) An analysis of the potential effects of an uncontained fire in causing other problems not related to safe shutdown, such as a release of contamination and impairment of operations;

(i) An analysis of the postfire recovery potential;

(j) An analysis of the emergency planning and coordination requirements necessary for effective loss control. This shall include any necessary compensatory measures to compensate for the failure or inoperability of any active or passive fire protection system or feature;

(k) An analysis for the protection of nuclear-safety-related systems and components from the inadvertent actuation or breaks in a fire protection system; and

(l) An analysis of the smoke control system, and the impact smoke can have on nuclear safety and operation for each fire area.

2-5 Procedures.

A formal procedure system for all actions pertaining to the fire protection program shall be established. This shall include:

(a) Inspection, testing, maintenance, and operation of fire protection systems and equipment, both manual and automatic, such as detection and suppression systems;

(b) Inspection, testing, and maintenance of passive fire protection features, such as fire barriers and penetration seals;

(c) Trend analysis requirements;

(d) Provisions for entering areas with access restrictions; and

(e) Training requirements.

2-6 Quality Assurance.

2-6.1

A quality assurance program shall be established in accordance with ASME NQA-1, Quality *Assurance Program Requirements for Nuclear Facilities*, for these aspects of the fire protection program related to nuclear safety:

(a) Design and procurement document control;

(b)* Instructions, procedures, and drawings;

(c)* Control of purchased material, equipment, and services;

(d)* Inspection;

(e)* Test and test control;

(f)* Inspection, test, and operating status;

(g)* Nonconforming items;

(h)* Corrective action;

(i)* Records; and

(j)* Audits.

2-6.2

The quality assurance program shall be documented in sufficient detail to verify its scope and adequacy.

2-7 Fire Emergency Plan.

A written fire emergency plan shall be established. As a minimum, this plan shall include:

(a) Response to fire and supervisory alarms;

(b) Notification of plant and public emergency forces;

(c) Evacuation of personnel;

(d) Coordination with security, maintenance, operations, and public information personnel;

(e) Fire extinguishment activities;

(f) Postfire recovery and contamination control activities;

(g) Control room operations during an emergency; and

(h) Prefire plan;

(i) A description of interfaces with emergency response organizations, security, safety, and others having a role in the fire protection program, including agreements with outside assistance agencies such as fire departments and rescue services.

2-8 Fire Brigade.

A plant fire brigade shall be established as indicated in Chapter 4.

Chapter 3 Fire Prevention and Administrative Controls

3-1 General.

3-1.1

This chapter sets forth the minimum requirements necessary for the administrative controls and fire prevention activities.

3-1.2*

This chapter applies to both normal operating modes and extended plant outages when fuel is removed from the reactor. However, additional requirements might be necessary during outages.

3-2 Plant Inspections.

3-2.1

The owner or his or her designated manager shall develop, implement, and update as necessary a fire prevention surveillance plan integrated with recorded rounds to all accessible sections of the plant.

3-2.2

Inspections of the plant shall be conducted in accordance with NFPA 601, *Standard on Guard Service in Fire Loss Prevention*. A prepared checklist shall be used for the inspection. Areas of primary containment and high radiation areas normally inaccessible during plant operation shall be inspected as plant conditions permit but at least during each refueling outage. The results of each inspection shall be documented and retained for two years.

Exception: For those plant areas inaccessible for periods greater than two years, the most recent inspection shall be retained.

3-3 Control of Combustible Materials.

3-3.1*

Plant administrative procedures shall specify appropriate requirements governing the storage, use, and handling of flammable and combustible liquids and flammable gases.

3-3.1.1* An inventory of all temporary flammable and combustible materials shall be made for each fire area, identifying the location, type, quantity, and form of the materials.

3-3.1.2* Temporary but predictable and repetitive concentrations of flammable and combustible materials shall be considered.

3-3.1.3 Combustibles, other than those that are an inherent part of the operation, shall be restricted to designated storage compartments or spaces.

3-3.1.4 Consideration shall be given to reducing the fire hazard by limiting the amount of combustible materials.

3-3.1.5 The storage and use of hydrogen shall be in accordance with NFPA 50A, *Standard for Gaseous Hydrogen Systems at Consumer Sites*, and NFPA 50B, *Standard for Liquefied Hydrogen Systems at Consumer Sites*.

3-3.1.6 The temporary use of wood shall be minimized. Plant administrative procedures shall specify that if wood must be used in the power block it shall be listed pressure-impregnated fire-retardant lumber.

3-3.2 Housekeeping.

3-3.2.1 Housekeeping shall be performed in such a manner as to minimize the probability of fire.

3-3.2.2 Accumulations of combustible waste material, dust, and debris shall be removed from the plant and its immediate vicinity at the end of each work shift or more frequently as necessary for safe operations.

3-3.3 Transient Combustible Loading.

3-3.3.1* Plant administrative procedures shall require that the total fire loads, including temporary and permanent combustible loading, will not exceed those quantities established for extinguishment by permanently installed fire protection systems and equipment.

Exception: Where limits are temporarily exceeded, the plant fire protection manager shall assure that appropriate fire protection measures are provided.

3-3.3.2 The fire protection manager or his or her designated representative shall conduct weekly walk-through inspections to ensure implementation of required controls. During major maintenance operations, the frequency of these walk-throughs shall be increased to daily. The results of these inspections shall be documented and the documentation retained for a minimum of two years.

3-3.3.3 When the work is completed, the plant fire protection manager shall have the area inspected to confirm that transient combustible loadings have been removed from the area. Extra equipment shall then be returned to its proper location. The results of this inspection shall be documented and retained for two years.

3-3.3.4* Only noncombustible panels or flame-retardant tarpaulins or approved materials of equivalent fire-retardant characteristics shall be used. Any other fabrics or plastic films used shall be certified to conform to the large-scale fire test described in NFPA 701, *Standard Methods of Fire Tests for Flame-Resistant Textiles and Films*.

3-3.4 Flammable and Combustible Liquids.

3-3.4.1 Flammable and combustible liquid storage and use shall be in accordance with NFPA 30, *Flammable and Combustible Liquids Code*. Where oil-burning equipment, stationary combustion engines, or gas turbines are used, they shall be installed and used in accordance with NFPA 31, *Standard for the Installation of Oil-Burning Equipment*, or NFPA 37, *Standard for the Installation and Use of Stationary Combustion Engines and Gas Turbines*, as appropriate.

3-3.4.2 Flammable and combustible liquid and gas piping shall be in accordance with ANSI B31.1, *Code for Power Piping*, or ASME *Boiler and Pressure Vessel Code*, Section III, as applicable.

3-3.4.3 Hydraulic systems shall use only listed fire-resistant hydraulic fluids.

Exception: Where unlisted hydraulic fluids must be used, they shall be protected by a fire suppression system.

3-3.4.4 The ignition of leaked or spilled liquid shall be minimized by:

(a)* Keeping the liquid from contact with hot parts of the steam system (wall temperature greater than or equal to ignition temperature), such as steam pipes and ducts, entry valve, turbine casing, reheater, and bypass valve;

(b) Using suitable electrical equipment;

(c) Sealing the insulation of hot plant components to prevent liquid saturation;

(d) Using concentric piping; and

(e) Using liquid collection systems.

3-4 Control of Ignition Sources.

Plant administrative procedures shall require an in-plant review and prior approval of all work plans to assess potential fire hazard situations. Where such conditions are determined to exist, special precautions shall be taken to define appropriate conditions under which the work is authorized.

3-4.1 Hot Work.

3-4.1.1 The owner or his or her designated manager shall develop, implement, and update as necessary a welding and cutting safety procedure using NFPA 51B, *Standard for Fire Prevention in Use of Cutting and Welding Processes*, and NFPA 241, *Standard for Safeguarding Construction, Alteration, and Demolition Operations*, as a guide.

3-4.1.2 Written permission from the fire protection manager or a designated alternate shall be obtained before starting activities involving cutting, welding, grinding, or other potential ignition sources.

3-4.1.3* A permit shall not be issued until:

(a) An inspection has determined that hot work can be safely conducted at the desired location,

(b) Combustibles have been moved away or safely covered,

(c) The atmosphere is nonflammable, and

(d) A trained fire watch (with equipment) is posted for the duration of the work, and for 30 min thereafter, to protect against sparks or hot metal starting fires.

3-4.1.4 All cracks or openings in floors shall be safely covered or closed.

3-4.2 Smoking.

3-4.2.1 Smoking shall be prohibited at or in the vicinity of hazardous operations or combustible and flammable materials. “No Smoking” signs shall be posted in these areas.

3-4.2.2 Smoking shall be permitted only in designated and supervised safe areas of the plant. Where smoking is permitted, safe receptacles shall be provided for smoking materials.

3-4.3 Temporary Electrical Wiring.

The ignition of flammable materials shall be minimized by requiring that all temporary electrical wiring:

(a) Be kept to a minimum;

(b) Be suitable for the location;

(c) Be installed and maintained in accordance with NFPA 70, *National Electrical Code®*, or ANSI C2, *National Electrical Safety Code*, as appropriate;

(d) Be arranged so that energy shall be isolated by a single switch; and

(e) Be arranged so that energy shall be isolated when not needed.

3-4.4 Temporary Heating Appliances.

3-4.4.1 Only safely installed, approved heating devices shall be used in all locations. Ample clearance shall be provided around stoves, heaters, and all chimney and vent connectors to prevent ignition of adjacent combustible materials in accordance with NFPA 211, *Standard for Chimneys, Fireplaces, Vents, and Solid Fuel-Burning Appliances* (connectors and solid fuel); NFPA 54, *National Fuel Gas Code* (fuel gas appliances); and NFPA 31, *Standard for the Installation of Oil-Burning Equipment* (liquid fuel appliances).

3-4.4.2 Refueling operations of heating equipment shall be conducted in an approved manner.

3-4.4.3 Heating devices shall be situated so that they are not likely to overturn.

3-4.4.4 Temporary heating equipment, when utilized, shall be monitored and maintained by properly trained personnel.

3-4.5

Open-flame or combustion-generated smoke shall not be used for leak testing.

3-4.6

Plant administrative procedures shall specify appropriate requirements governing the control of electrical appliances in all plant areas.

3-5 Temporary Structures.

3-5.1 Exterior Buildings.

3-5.1.1* Temporary buildings, trailers, and sheds, whether individual or grouped shall be constructed of noncombustible material and shall be separated from other structures. (*See NFPA 80A, Recommended Practice for Protection of Buildings from Exterior Fire Exposures.*)

3-5.1.2 Temporary buildings, trailers, and sheds and other structures constructed of combustible or limited-combustible material shall be separated from other structures by a minimum distance of 30 ft (9.1 m).

Exception: Where all portions of the exposed building (i.e., walls, roof, etc.) within 30 ft (9.1 m) of the exposure constitute a rated fire barrier, the minimum separation distance shall be permitted to be reduced in accordance with Table 3-5.1.2.

Table 3-5.1.2 Minimum Separation Distances

Exposed Building Fire Barrier Rating	Minimum Distance Where Exposing Building Is Without Protection	Minimum Distance Where Exposing Building Has Automatic Sprinklers
3 hr	5 ft (1.5 m)	0 ft (0 m)
2 hr	10 ft (3.0 m)	5 ft (1.5 m)
1 hr	20 ft (6.1 m)	10 ft (3.0 m)
< 1 hr	30 ft (9.1 m)	15 ft (4.6 m)

3-5.1.3 All exterior buildings, trailers, sheds, and other structures shall have the appropriate type and size of portable fire extinguishers.

3-5.2 Exterior Temporary Coverings.

Where coverings are utilized for protection of the outdoor storage of materials or equipment, the following shall apply:

(a) Only approved fire-retardant tarpaulins or other acceptable materials shall be used;

(b) All framing material used to support such coverings shall be either noncombustible or fire-retardant pressure-impregnated wood; and

(c) Covered storage shall not be located within 30 ft (9.1 m) of any building.

3-5.3 Interior Temporary Facilities.

3-5.3.1 All interior temporary structures shall be constructed of noncombustible, limited-combustible, or fire-retardant pressure-impregnated wood. Structures constructed of noncombustible or limited-combustible materials shall be protected by an automatic fire suppression system unless the fire hazard analysis determines that automatic suppression is not required. The structure shall be protected by an automatic fire suppression system if the structure is constructed of fire-retardant pressure-impregnated wood.

3-5.3.2 This use of interior temporary coverings shall be limited to special conditions where interior temporary coverings are necessary. They shall be constructed of approved fire-retardant tarpaulins.

3-5.3.3 Where framing is required, it shall be constructed of noncombustible, limited-combustible, or fire-retardant pressure-impregnated wood.

3-5.3.4 All interior temporary facilities shall have the appropriate type and size of portable fire extinguisher.

3-6 Impairments.

3-6.1*

A written procedure shall be established to address impairments to fire protection systems and features and other plant systems that directly impact the level of fire risk (e.g., ventilation systems, plant emergency communication systems, etc.).

3-6.2*

Impairments to fire protection systems shall be as short in duration as practical.

3-6.3*

Appropriate post-maintenance testing shall be performed on equipment that was impaired to ensure that the system will function properly. Any change to the design or function of the system after the impairment shall be considered in establishing the testing requirements and shall be reflected in the appropriate design documents and plant procedures.

3-7 Testing and Maintenance.

3-7.1

Upon installation, all new fire protection systems and passive fire protection features shall be preoperationally inspected and tested in accordance with applicable NFPA standards. Where appropriate test standards do not exist, inspections and test procedures described in the purchase and design specification shall be followed.

3-7.2*

Fire protection systems and passive fire protection features shall be inspected, tested, and maintained in accordance with applicable NFPA standards, manufacturers' recommendations, and requirements established by those responsible for fire protection at the plant.

3-7.3

Inspection, testing, and maintenance shall be performed using established procedures with written documentation of results and a program of follow-up actions on discrepancies.

3-7.4*

Consideration shall be given to the inspection, testing, and maintenance of nonfire protection systems and equipment that have a direct impact on the level of fire risk within the plant.

Chapter 4 Manual Fire Fighting

4-1 Prefire Plans.

4-1.1

Detailed prefire plans shall be developed for all site areas.

4-1.2*

The plans shall detail the fire area configurations and fire hazards to be encountered in the fire area along with any safety-related components and fire protection systems and features that are present.

4-1.3

Prefire plans shall be reviewed and, if necessary, updated at least every two years.

4-1.4*

Prefire plans shall be available in the control room and made available to the plant fire brigade.

4-2* On-Site Fire-Fighting Capability.

4-2.1 General.

4-2.1.1 A minimum of five plant fire brigade members shall be available for response at all times.

4-2.1.2 Fire brigade members shall have no other assigned normal plant duties that would prevent immediate response to a fire or other emergency as required.

4-2.1.3 The brigade leader and at least two brigade members shall have sufficient training and knowledge of plant safety-related systems to understand the effects of fire and fire suppressants on safe shutdown capability.

4-2.1.4 The fire brigade shall be notified immediately upon verification of a fire or fire suppression system actuation.

4-2.2 Fire Fighter Qualifications and Requirements.

4-2.2.1 Plant fire brigade members shall be physically qualified to perform the duties assigned.

4-2.2.2 Each member shall pass an annual physical examination to determine that the fire brigade member can perform strenuous activity.

4-2.2.3 The physical examination shall determine each member's ability to use respiratory protection equipment.

4-2.3

Each fire brigade member shall meet training qualifications as specified in Section 4-3.

4-3 Training and Drills.

4-3.1 Plant Fire Brigade Training.

4-3.1.1 Plant fire brigade members shall receive training consistent with the requirements contained in NFPA 600, *Standard on Industrial Fire Brigades*, or NFPA 1500, *Standard on Fire Department Occupational Safety and Health Program*, as appropriate.

4-3.1.2 Fire brigade members shall be given quarterly training and practice in fire fighting. This includes radioactivity and health physics considerations to ensure that each member is thoroughly familiar with the steps to be taken in the event of a fire; this training will contribute to maintaining the best possible preparedness for such contingencies.

4-3.1.3 A written program shall detail the fire brigade training program.

4-3.1.4 Written records that include, but are not limited to, initial fire brigade classroom and hands-on training, refresher training, special training schools attended, drill attendance records, and leadership training for fire brigades shall be maintained for each fire brigade member.

4-3.2 Drills.

4-3.2.1 Drills shall be conducted quarterly for each shift to test the response capability of the fire brigade.

4-3.2.2 Fire brigade drills shall be developed to test and challenge fire brigade response including brigade performance as a team, proper use of equipment, effective use of pre-fire plans, and coordination with other groups.

4-3.2.3 Fire brigade drills shall be conducted in various plant areas, especially in those areas identified by the fire hazards analysis to be critical to plant operation and to contain significant fire hazards.

4-3.2.4 Drill records shall be maintained detailing the drill scenario, fire brigade member response, and ability of the fire brigade to perform the assigned duties.

4-3.2.5 A critique shall be held after each drill.

4-4 Fire-Fighting Equipment.

4-4.1

The plant fire brigade shall be provided with equipment that will enable them to adequately perform their assigned tasks. This would include but not be limited to protective clothing, respiratory protective equipment, radiation monitoring equipment, personal dosimeters, and fire suppression equipment such as hoses, nozzles, fire extinguishers, etc.

4-4.2

Fire brigade equipment shall be tested and maintained. Written records shall be retained for review.

4-5 Off-Site Fire Department Interface.

4-5.1 Mutual Aid Agreement.

4-5.1.1 A mutual aid agreement shall be offered to the local off-site fire department.

4-5.1.2 Where possible, the plant fire protection manager and the off-site fire authorities shall develop a plan for their interface. The fire protection manager also shall consult with the off-site fire department to make plans for fire fighting and rescue, including assistance from other organizations, and to maintain these plans.

4-5.1.3 The local off-site fire department shall be invited to participate in an annual drill.

4-5.2 Site-Specific Training.

4-5.2.1 Fire fighters from the off-site fire department who are expected to respond to a fire at the plant shall be familiar with the plant layout.

4-5.2.2 The access routes to fires in the controlled area (to which access doors are locked) shall be planned in advance.

4-5.2.3* The off-site fire department shall be offered instruction and training in radioactive materials, radiation, and hazardous materials that might be present.

4-5.3 Security and Health Physics.

4-5.3.1* Plant management shall designate a plant position to act as a liaison to the off-site fire department when they respond to a fire or other emergency at the plant.

4-5.3.2 Plant management shall ensure that the off-site fire department personnel are escorted at all times and emergency actions are not delayed.

4-6 Water Drainage.

The fire brigade shall have at their disposal the necessary equipment to assist with routing water from the affected area.

4-7 Fire-Fighting Access.

4-7.1

All plant areas shall be accessible for fire-fighting purposes.

4-7.2

Prefire plans shall identify those areas of the plant that are locked and have limited access for either security or radiological control reasons. Provisions shall be made to allow access to these areas. If necessary, this shall include having security and health physics personnel respond to the fire area along with the fire brigade. Health physics personnel shall confer with the fire brigade leader to determine the safest method of access to any radiologically controlled area.

4-8 Radiation Shielding.

4-8.1

Full advantage shall be taken of all fixed radiation shielding to protect personnel responding for fire suppression purposes.

4-8.2

Health physics personnel shall advise the fire brigade leader of the best method for affording radiological protection.

4-9* Smoke and Heat Removal.

If fixed ventilation systems are not capable of removing smoke and heat, the fire brigade shall utilize portable ventilation equipment. (*See Section 6-4.*)

Chapter 5 Nuclear Reactor Safety Considerations

5-1 General.

Ensuring the safety of the public, the environment, and plant personnel during and after a fire event is paramount to this standard. The purpose of this chapter is to define the minimum criteria necessary to ensure that the reactor and any support facilities are capable of achieving and maintaining safe plant conditions in the event of a fire and minimizing the release of radioactive material.

5-2 Fire Hazards and Safe Shutdown Analysis.

A fire safe shutdown analysis (FSSA) shall be prepared and maintained for the operating life of the reactor. The FSSA shall include as a minimum:

(a) Fire hazards analysis (FHA),

(b) Safe shutdown analysis (SSA), and

(c) Internal plant examination of external fire events for severe accident vulnerabilities.

5-2.1 Fire Hazards Analysis.

The fire hazards analysis shall include the criteria indicated in Section 2-4.

5-2.2 Safe Shutdown Analysis.

A safe shutdown analysis of the effects of a fire on those essential structures, systems, and components required to safely shut down the plant and maintain it in a safe shutdown condition shall be performed. The analysis shall include as a minimum the requirements of this section.

5-2.2.1 A safe shutdown system available/unavailable calculation or table shall be prepared and maintained for each fire area. This document shall identify all safe shutdown equipment that is operable or inoperable due to the effects of a fire in that fire area. This document shall demonstrate compliance with the requirements of Sections 5-3 and 5-4.

5-2.2.2* A shutdown logic diagram shall be available that identifies the conditions necessary to achieve and maintain safe shutdown capability in the event of a fire and those plant features necessary to realize these conditions, including auxiliary and support features.

5-2.3 Internal Plant Examination of External Fire Events for Severe Accident Vulnerabilities.

A risk assessment that estimates the potential risk from a fire in relation to the plant's core damage frequency shall be prepared.

5-2.3.1* An industry-accepted examination process shall be used for the risk assessment.

5-2.3.2* An acceptable risk assessment shall demonstrate that the probability of core damage as a result of an internal fire is less than 1×10^{-6} per reactor year.

5-2.3.3 The internal plant examination of external fire events for severe accident vulnerabilities shall be used to evaluate the level of safety of the plant and shall not be used to reduce the overall plant fire protection design basis.

5-3 Design Basis Events and Requirements.

5-3.1 Fire.

5-3.1.1 Only one fire is assumed to occur at a given time. For the purpose of a safe shutdown analysis, damage shall be assumed to occur immediately.

5-3.1.2* All components, including electrical cables, that are susceptible to fire damage in a single fire area (except primary containment and annulus areas) shall be assumed to be disabled or to be spuriously actuated, whichever is the worst case.

5-3.1.3* A fire shall not be assumed to impair safe shutdown capability inside primary containment or annulus areas.

5-3.1.4 The plant shall be assumed to be operating at 100 percent power, with all components in their normal configuration, when a postulated fire occurs. The analysis also shall consider changes in plant configurations during all normal modes of operation.

5-3.1.5 A concurrent single active component failure independent of the postulated fire shall not be assumed to occur.

5-3.1.6 Plant accidents or severe natural phenomena are not assumed to occur concurrently with a postulated fire.

Exception: For seismic/fire interaction, see 5-3.2.

5-3.1.7 A loss of off-site power shall be assumed concurrent with the postulated fire only where the safe shutdown analysis (including alternative shutdown) indicates the fire could initiate the loss of off-site power.

5-3.1.8 Fire safe shutdown components shall be capable of performing the following functions in the event of the postulated fire:

(a) Achieving and maintaining subcritical reactivity conditions in the reactor;

(b) Maintaining the reactor coolant inventory such that plant safety limits are not violated;

(c)* Establishing reactor decay heat removal to prevent fuel damage and achieve and maintain cold shutdown conditions;

(d) Providing support functions such as process cooling, lubrication, etc., necessary to permit operation of the FSSD components; and

(e) Providing direct readings of the process variables necessary to perform and control the FSSD functions.

5-3.1.9 Limiting Safety Conditions. During a postfire shutdown, the fission product boundary integrity shall be maintained within acceptable limits (e.g., fuel clad damage, rupture of any primary coolant boundary, or rupture of the primary containment boundary).

5-3.1.10 Spurious Signals.

5-3.1.10.1 An evaluation of spurious signals shall be performed based on these assumptions:

(a) All potential spurious components shall be assumed to be in their normal operating positions for the particular mode of operation being considered by the spurious signal evaluation.

(b) The fire-induced cable damage shall determine if any of the following cable failure modes are possible:

1. *Hot Short.* Individual conductors within a cable are shorted to individual conductors of a different cable such that a de-energized circuit might become energized by shorting to an external source of electrical power;

2. *Open Circuit.* The cable failure results in the loss of electrical continuity;

3. *Shorts to Ground.* Cable conductors short to grounded structures; or

4. *Short Circuit.* Individual conductors within multi-conductor cable short to each other.

5-3.1.10.2 Functional failure or damage modes of equipment and components that can spuriously operate shall be considered.

5-3.1.11 Fire-Induced Spurious Actuation. The following postulates shall be used when analyzing fire-induced spurious actuation of equipment.

5-3.1.11.1 FSSD capability shall not be adversely affected by simultaneous spurious actuation of all valves in a single high-to-low pressure interface line where the power or control circuits for the valves can be damaged by a postulated fire.

5-3.1.11.2 For other than high-to-low pressure boundaries, FSSD capability shall not be adversely affected by spurious actuation or signal.

5-3.1.11.3 Separate conditions shall be analyzed concurrent with the spurious actuation(s) or signal addressed in 5-3.1.10.1 and 5-3.1.10.2.

5-3.1.11.4 All automatic functions (signal, logic, etc.) from the circuits that can be damaged by the postulated fire shall be assumed lost or assumed to function as intended, whichever is the worst case.

5-3.1.11.5 All potential spurious signals shall be analyzed. However, only one spurious signal shall be postulated to occur at a time for purposes of analysis, except for high-low pressure interface valves.

5-3.1.12* For the purpose of analysis for cases involving high-to-low pressure interface, hot shorts involving three-phase ac circuits shall be postulated.

5-3.1.13 For ungrounded dc circuits, if it can be shown that only two hot shorts of the proper polarity without grounding could cause spurious operation, no further evaluation shall be necessary except for cases involving high-to-low pressure interfaces.

5-3.1.14* All associated circuits of concern shall be isolated from FSSD circuits by coordinated circuit breakers or fuses.

5-3.1.15* Circuits Associated by Common Enclosure.

5-3.1.15.1 Protection for circuits associated by common enclosure shall be demonstrated by ensuring that suitable electrical overcurrent protection devices are provided for all cables. Appropriate measures to prevent the propagation of fire, such as rated fire stops and seals in the raceway or enclosure, shall be provided.

5-3.1.15.2 The overcurrent protection devices shall be located outside of the fire area containing the common enclosure.

5-3.1.16 High Impedance Faults.

5-3.1.16.1 A high impedance fault shall be assumed to occur as a result of a fire.

5-3.1.16.2 Evaluation of the impact of high impedance faults on the ability to achieve and maintain safe shutdown shall be performed. This evaluation shall demonstrate that there is sufficient capacity in the electrical protective system to preclude a trip of the main source breaker to the supply.

5-3.2* Seismic/Fire Interaction.

5-3.2.1 A risk assessment that demonstrates the potential risk from a seismically induced fire in relationship to the plant's core damage frequency shall be prepared.

5-3.2.2* An industry-accepted examination process shall be used for the risk assessment.

5-3.2.3 The assessment shall be used to evaluate the level of safety of the plant. This assessment shall not be used to reduce the overall plant fire protection design basis.

5-4 Separation Criteria.

5-4.1

One safety division of systems that is necessary to achieve and maintain safe shutdown from either the control room or emergency control station(s) shall be maintained free of fire damage by a single fire, including an exposure fire.

5-4.2

One safety division of systems that is necessary to prevent the initiation of a design basis accident shall be maintained free of fire damage from a single fire that occurs outside the main control room.

5-4.3

Redundant cables, equipment, components, and associated circuits of nuclear-safety-related or safe shutdown systems shall be located in separate fire areas. The fire barrier forming these fire areas shall have a 3-hr fire rating and automatic area-wide detection shall be installed throughout these fire areas. Structural steel forming a part of or supporting such fire barriers shall be protected to provide fire resistance equivalent to that of the barrier.

Exception No. 1: Where redundant system separation inside containment cannot be achieved, other measures shall be permitted in accordance with Section 5-6 to prevent a fire from causing the loss of function of nuclear-safety-related or safe shutdown systems.

Exception No. 2: Redundant cables, equipment, components, and associated circuits of nuclear-safety-related or safe shutdown systems shall be located in separate fire areas. The fire barriers forming these fire areas shall have a minimum fire-resistive rating of 1 hr and automatic area-wide detection and suppression shall be installed throughout these fire areas. Structural steel forming a part of or supporting such fire barriers shall be protected to provide fire resistance equivalent to that of the barrier.

5-4.4

Fire areas separated by minimum 3-hr fire barriers shall be established to separate redundant safety divisions and safe shutdown functions from fire hazards in nonsafety or safe shutdown related areas of the plant.

5-4.5

Within fire areas containing components of either a nuclear-safety-related or safe shutdown system, special attention shall be given to detecting and suppressing fire that can adversely affect the system. Measures that shall be taken to reduce the effects of a postulated fire in a given fire area include limiting the amount of combustible materials (*see Section 3-3*), providing fire-rated barriers between major components and equipment to limit fire spread within a fire area (*see Section 6-1*), or installing fire de- tection (*see Section 7-8*) and fixed suppression systems (*see Section 7-6*).

5-5 Manual Actions.

5-5.1 Shutdown Procedures.

Procedures shall be developed for actions necessary to achieve FSSD.

5-5.2 Operator Actions.

5-5.2.1 Operator actions necessary to achieve FSSD of the reactor shall be kept to a minimum.

5-5.2.2* No credit shall be taken for operator actions required to effect repairs to equipment in order to achieve FSSD of the reactor.

5-5.2.3 Personnel necessary to achieve and maintain the plant in FSSD following a fire shall be provided from the normal on-site staff, exclusive of the fire brigade.

5-5.2.4 The operator training program shall include performance-based simulator training on FSSD procedures.

5-5.2.5 Walk-through of operator actions necessary to achieve FSSD of the reactor shall be performed to verify that the actions are feasible and shall be integrated into the operator training program.

5-5.2.6 Postfire shutdown and recovery plans shall be included in the station emergency preparedness plan. Drills and operator requalification training shall ensure that operations personnel are familiar with and can accomplish the necessary actions.

5-5.3 Operator Access and Equipment Operation.

5-5.3.1 Operator Access.

5-5.3.1.1* Access routes to areas containing equipment necessary for safe shutdown of the reactor shall be protected from the effects of smoke and fire.

5-5.3.1.2 Two separate access routes shall be provided from the main control room to the remote shutdown location.

5-5.3.1.3 Emergency lighting shall be provided for the access routes and the remote shutdown location (*see Section 6-6*).

5-5.3.2 Equipment Operation.

5-5.3.2.1* Operator safety shall not be threatened by fire conditions while implementing FSSD of the reactor.

5-5.3.2.2* Operation of equipment required to effect FSSD of the reactor shall not require any extraordinary actions by the operator.

5-5.3.2.3 Operators (e.g., handwheels of valves that require manual manipulation for FSSD) shall be readily accessible. If the handwheel is located more than 5 ft (1.5 m) above the floor, it shall be provided with either a chain operator or a permanent platform. The platform shall be of sufficient size to allow the operator to safely perform the manual action.

5-6 Alternative Shutdown Capability.

5-6.1

Alternative shutdown capability provided for a specific fire area shall include achieving and maintaining subcritical reactivity conditions in the reactor, maintaining the reactor coolant inventory, achieving safe shutdown, and maintaining safe shutdown following the fire event.

5-6.2

During the postfire shutdown, the reactor coolant system process variables shall be maintained within those predicted for a loss of normal ac power, and the fission product boundary integrity shall not be affected.

5-6.3

Performance goals for reactor shutdown functions shall be the same as those required by 5-3.1.8.

5-6.4

The safe shutdown circuits for each fire area shall be known to be isolated from associated circuits in the fire area so the hot shorts, shorts to ground, open circuits, or short circuits will not prevent the operation of the safe shutdown equipment. Isolation of associated circuits from the safe shutdown equipment shall be such that a postulated fire involving the associated circuits will not prevent safe shutdown or damage the safe shutdown components.

Chapter 6 General Plant Design

6-1 Plant Arrangement.

6-1.1 Building Separation.

6-1.1.1 In multi-unit plants, each unit shall be separated from adjacent units by either an open space of at least 50 ft (15.2 m), or at least a 3-hr-rated fire barrier.

6-1.1.2 Buildings or portions thereof containing nuclear-safety-related systems shall be separated from buildings or portions thereof not related to nuclear safety by barriers having a designated fire resistance rating of 3 hr.

Exception: Buildings containing nuclear-safety-related systems shall be permitted to be separated from buildings not related to nuclear safety by an open space of at least 50 ft (15.2 m).

6-1.2 Fire Areas.

Advanced light water reactor (ALWR) electric generating plants shall be subdivided into separate fire areas to minimize the risk of fire spread and the resultant consequential damage from fire gases, smoke, heat, radioactive contamination, and fire-fighting activities. In addition, the subdivision into fire areas shall allow adequate access for manual fire suppression activities.

6-1.2.1 A listed fire barrier having a fire resistance rating of at least 3 hr, and with listed 3-hr-rated penetration seals, shall be provided as follows:

(a) To separate all contiguous buildings or portions thereof serving different purposes, such as reactor containment, auxiliary, turbine, rad waste, control, service, administration, and other occupancy areas as dictated by reactor design;

(b) To separate safety-related standby emergency diesel generators and combustion turbines from each other and the rest of the plant;

(c) To separate the turbine generator lube oil conditioning system and lube oil storage from the turbine building and adjacent areas;

(d) To separate diesel fire pumps and associated equipment from other pumps in the same pump house;

(e) To separate all areas with heavy concentrations of cables, such as cable spreading rooms, cable tunnels, cable penetration areas, and cable shafts or chases, including those within the reactor containment, from adjacent areas;

(f) To separate auxiliary boiler rooms from adjacent areas; and

(g) Wherever so determined by the fire hazards analysis.

6-1.2.2 To prevent vertical spread of fire, stairways, elevator shafts, trash chutes, and other vertical shafts and plenums shall be enclosed with barriers having a fire resistance rating of at least 2 hr. Openings in such barriers shall be protected with listed automatic or self-closing fire doors having a fire protection rating of at least $1^1/_2$ hr.

6-1.3 Openings in Fire Barriers.

6-1.3.1 All openings in fire barriers shall be provided with fire door assemblies, fire dampers, penetration seals (fire stops), or other approved means having a fire protection rating consistent with the designated fire resistance rating of the barrier.

Exception: The use of assemblies that are not listed or approved due to nuclear safety or security requirements shall be demonstrated to be equivalent.

6-1.3.2 Fire door assemblies, fire dampers, and fire shutters used in 2-hr-rated fire barriers shall be listed as not less than $1^1/_2$ hr rated and shall meet the requirements of NFPA 80, *Standard for Fire Doors and Fire Windows*, for fire door requirements and NFPA 90A, *Standard for the Installation of Air Conditioning and Ventilating Systems*, for fire damper requirements.

Exception: Where approved full-scale fire tests indicate that opening protection is not necessary, opening protection shall not be required.

6-1.3.2.1 Windows in fire barriers, such as for a control room or computer room, shall be provided with a listed or approved fire shutter or automatic wall curtain.

6-1.3.2.2 Cable openings, piping openings, and building joints shall be provided with fire-rated penetration seals. The sealing material shall be of limited-combustible or noncombustible material and shall meet the requirements of ASTM E 814, *Fire Tests of Through-Penetration Fire Stops*, or UL 1479, *Standard for Safety Fire Tests of Through-Penetration Firestops*.

6-1.3.2.3 Internal Conduit Seals. All conduits shall be sealed at the barrier with a fire-rated seal, if accessible. Alternatively, internally sealing with a fire-rated seal at the first break in the conduit on both sides of the barrier shall be acceptable. For the above configuration, the fire rating of the internal conduit seal shall be equivalent to the rating of the fire barrier being penetrated.

Exception: Where approved full-scale fire tests indicate that internal conduit seals are not necessary, internal conduit seals are not required.

6-1.3.2.4 All fire-rated assemblies shall be tested with a positive pressure in the furnace.

6-1.3.2.5 Normally closed fire doors in fire barriers shall be identified with a sign indicating, "Fire Door — Keep Closed."

6-1.3.3 Design features that provide for monitoring and control of fire doors to assure fire door operability and fire barrier integrity shall be provided.

Exception: Administrative procedures instead of design features shall be permitted.

6-2 Life Safety.

6-2.1*

NFPA *101*,® *Life Safety Code*,® shall be the standard for life safety from fire in the design and operation of the ALWR, except where modified by this standard.

6-2.2*

The majority of the areas involved in the transfer of nuclear energy to electrical energy shall be considered as special-purpose industrial occupancies and special structure, windowless buildings, as defined in NFPA *101*, *Life Safety Code*.

6-2.3

In determining the exits for an ALWR plant, the actual number of personnel and occupancy hazards during maintenance, refueling, and testing shall determine the exit requirements and occupant load based upon NFPA *101*, *Life Safety Code*.

6-2.4

Cafeterias, lunchrooms, conference rooms, and assembly rooms having an occupant load greater than 50 shall conform to the new assembly occupancy requirements in NFPA *101*, *Life Safety Code*.

6-2.5

General office areas, office buildings, and training facilities shall conform to the business occupancy requirements in NFPA *101*, *Life Safety Code*.

6-2.6

Warehouses and storage areas shall conform to the storage occupancy requirements in NFPA *101*, *Life Safety Code*.

6-3 Building and Construction Materials.

6-3.1

Construction materials for the ALWR plant shall be classified by at least one of the following test methods appropriate to the end-use configuration of the material:

(a) NFPA 220, *Standard on Types of Building Construction*;

(b) ASTM E 136, *Standard Test Method for Behavior of Materials in a Vertical Tube Furnace at 750°C*;

(c) NFPA 251, *Standard Methods of Tests of Fire Endurance of Building Construction and Materials* (ASTM E 119, *Standard Test Methods for Fire Tests of Building Construction and Materials*);

(d) NFPA 253, *Standard Method of Test for Critical Radiant Flux of Floor Covering Systems Using a Radiant Heat Energy Source*;

(e) NFPA 255, *Standard Method of Test of Surface Burning Characteristics of Building Materials* (ASTM E 84, *Standard Test Method for Surface Burning Characteristics of Building Materials*);

(f) NFPA 256, *Standard Methods of Fire Tests of Roof Coverings*; or

(g) NFPA 259, *Standard Test Method for Potential Heat of Building Materials*.

6-3.2*

All walls, floors, and structural components, except interior finish materials, shall be of noncombustible construction.

6-3.2.1 Interior wall or ceiling finish classification shall be in accordance with NFPA *101*, *Life Safety Code*, requirements for Class A material.

6-3.2.2 Interior floor finish classification shall be in accordance with NFPA *101*, *Life Safety Code*, requirements for Class I interior floor finish.

6-3.3

Thermal insulation materials, radiation shielding materials, ventilation duct materials, soundproofing materials, and suspended ceilings, including light diffusers and their supports, shall be noncombustible or limited combustible.

6-3.4

Electrical wiring above suspended ceilings shall be kept to a minimum. Electrical wiring shall be listed for plenum use, or armor-metal-jacketed, or routed in metallic conduits, or trays having both solid metallic bottoms and covers.

6-3.5

Roof coverings shall be Class A as determined by tests described in NFPA 256, *Standard Methods of Fire Tests of Roof Coverings*.

6-3.6

Metal roof deck construction shall be Class I as listed by Factory Mutual or fire acceptable as listed by Underwriters Laboratories Inc.

6-3.7

Bulk flammable gas storage, either compressed or cryogenic, shall not be permitted inside structures housing safety-related systems.

6-3.7.1 Storage of flammable gas, such as hydrogen, shall be located outdoors or in separate detached buildings, so that a fire or explosion will not adversely affect any safety-related systems or equipment.

6-3.7.2* Outdoor high pressure flammable gas storage containers shall be located so that the long axis is not pointing at the building walls.

6-3.8

Bulk storage of flammable and combustible liquids shall not be permitted inside structures housing safety-related systems. As a minimum, the storage and use shall comply with the requirements of NFPA 30, *Flammable and Combustible Liquids Code*.

6-4* Ventilation.

6-4.1*

The design, installation, and operation of ventilation systems necessary for normal and emergency operation of the plant shall be in accordance with NFPA 90A, *Standard for the Installation of Air Conditioning and Ventilating Systems.*

6-4.2*

Automatic damper closure or shutdown of ventilation systems shall be consistent with nuclear safety and safety of on-site personnel.

6-4.3

Smoke removal shall be provided for nuclear-safety-related areas of the plant. Equipment shall be suitable for removing smoke without damage to equipment. The release to the environment of smoke containing radioactive materials shall be monitored in accordance with emergency plans.

Exception: For those plants provided with complete automatic sprinkler protection, fixed ventilation systems for the removal of smoke is not required.

6-4.3.1 Smoke and heat removal systems shall be provided for other fire areas based upon the fire hazards analysis.

Exception: For those plants provided with complete automatic sprinkler protection, fixed ventilation systems for the removal of smoke is not required.

6-4.3.2 Smoke from nonnuclear areas shall be discharged directly outside to an area that will not adversely affect nuclear-safety-related areas.

6-4.3.3 Any ventilation system designed to exhaust potentially radioactive smoke or heat shall be evaluated to ensure that inadvertent operation or single failures will not violate the radiologically controlled areas of the plant. This includes containment functions for protecting the public and maintaining habitability for operations personnel.

6-4.4

To facilitate manual fire fighting, smoke control shall be provided in high-density cable-use areas, switchgear rooms, diesel fuel oil storage areas, turbine buildings, and other areas where potential exists for heavy smoke and heat conditions as determined by the fire hazards analysis.

6-4.5

The power supply and controls for mechanical ventilation systems used for smoke removal shall be routed outside the fire area served by the system or protected from fire damage.

6-4.6

The fresh air supply intakes to plant areas shall be located remote from the exhaust air outlets and smoke vents of other fire areas to minimize the possibility of contaminating the air intake with the products of combustion.

6-4.7

Enclosed stairwells shall be designed to minimize smoke infiltration during a fire.

6-4.8

Where natural-convection ventilation is used, a minimum ratio of vent area to floor area shall be at least 1 to 200, except in oil hazard areas, where at least a 1- to-100 ratio shall be provided.

6-4.9 Duct Systems.

6-4.9.1 Combustible ducts, including fire-retardant types, shall not be used for ventilation systems.

6-4.9.2 Interconnections of individual fire areas via the ventilation system shall be kept to a minimum.

6-4.9.3 Fire dampers shall be installed in accordance with NFPA 90A, *Standard for the Installation of Air Conditioning and Ventilating Systems*. Consideration shall be given to the velocity in the duct.

Exception No. 1: Where full-scale fire tests that are conducted by testing laboratories indicate that fire dampers are not necessary to prevent fire spread through a fire-rated barrier, fire dampers can be omitted from the fire barrier.

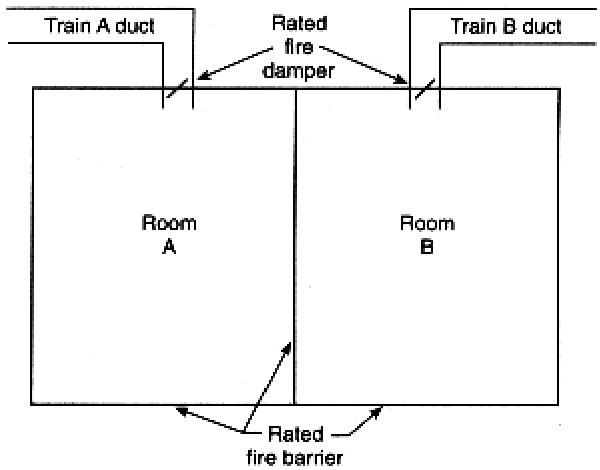
Exception No. 2: As an alternative to fire dampers, the duct system can be enclosed or constructed to provide the required fire barrier through adjacent areas. (Refer to Figure 6-4.9.)

6-4.9.4 Listed fire dampers having a rating of $1^1/_2$ hr shall be installed where ventilation ducts penetrate fire barriers having a required fire resistance rating of 2 hr. Where ventilation ducts penetrate required 3-hr fire barriers, approved fire dampers having a fire protection rating of 3 hr shall be installed.

6-4.9.5 Fire dampers shall be equipped for automatic closure by thermal release elements. The fire damper shall be mounted directly into the separating wall or the duct can be protected between the wall and the damper according to the fire resistance of the separating wall structure.

6-4.9.6 Fire dampers shall be designed and installed so that the air velocity in the ducts assists in closing fire dampers and does not preclude proper damper closure.

6-4.9.7 Ventilation ducts containing fire dampers shall be provided with access ports for ease of inspection and for replacement of the thermal element.



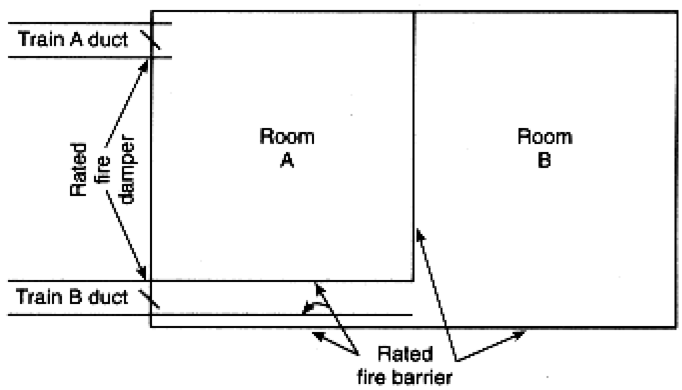


Figure 6-4.9 Typical air duct fire damper configuration.

6-4.10 Filters.

6-4.10.1 Air entry filters shall have approved noncombustible filter media that produce a minimum amount of smoke (UL Class 1) when subjected to heat.

6-4.10.2 In order to decrease the fire hazard of these filters and of oil-bath-type filters, only approved fire-resistive adhesives and oils with the Cleveland open-cup flash point (ASTM D 92, *Standard Test Method for Flash and Fire Points by Cleveland Open Cup*) equal to or greater than 464°F (240°C) and that do not produce appreciable smoke shall be used.

6-4.10.3 High-efficiency particulate air filters (HEPA) shall meet the requirements of UL 586, *Standard for Test Performance of High-Efficiency Particulate Air Filter Units*.

6-4.10.4 Fixed water spray systems shall be provided for charcoal adsorber beds containing more than 100 lb (45.4 kg) of charcoal.

6-4.10.5 Fire suppression systems shall be installed to protect filters that collect combustible material.

6-5 Drainage.

6-5.1*

Drainage shall be provided in all areas of the plant for the removal of all liquids directly to safe areas, or for containment in the area without adverse flooding of equipment and without endangering other areas.

6-5.2

Drainage and the prevention of equipment water damage shall be accomplished by one or more of the following:

(a) Floor drains,

(b) Floor trenches,

(c) Open doorways or other wall openings,

(d) Curbs for containing or directing drainage,

(e) Equipment pedestals, or

(f) Pits, sumps, and sump pumps.

6-5.3

Drainage and any associated drainage facilities for a given area shall be sized to accommodate the volume of liquid produced by all of the following:

(a) The spill of the largest single container of any flammable or combustible liquids in the area;

(b) Where automatic suppression is provided throughout, the credible volume of discharge (as determined by the fire hazards analysis) for the suppression system operating for a period of 30 min;

(c) Where automatic suppression is not provided throughout, the volume shall be based on a manual fire-fighting flow rate of 500 gal/min (1892.5 L/min) for a duration of 30 min, unless the fire hazards analysis demonstrates a different flow rate and duration;

(d)* Where automatic suppression is not provided throughout, the contents of piping systems and containers that are subject to failure in a fire; and

(e) Where the installation is outside, credible environmental factors such as rain and snow.

6-5.4

Floor drainage from areas containing flammable or combustible liquids shall be trapped to prevent the spread of burning liquids beyond the fire area.

6-5.5

Where gaseous fire suppression systems are installed, floor drains shall be provided with adequate seals, or the fire suppression system shall be sized to compensate for the loss of fire suppression agent through the drains.

6-5.6

Drainage facilities shall be provided for outdoor oil-insulated transformers, or the ground shall be sloped such that oil spills flow away from buildings, structures, and adjacent transformers.

6-5.6.1 Unless drainage from oil spills is accommodated by sloping the ground around transformers away from structures or adjacent equipment, consideration shall be given to providing curbed areas or pits around transformers.

6-5.6.2 If a layer of uniformly graded stone is provided in the bottom of the curbed area or pit as a means of minimizing ground fires, the following shall be assessed:

(a) The sizing of the pit shall allow for the volume of the stone, and

(b) The design shall address the possible accumulation of sediment or fines in the stone.

6-5.7

For facilities consisting of more than one generating unit, a curb or trench drain shall be provided on solid floors where the potential exists for an oil spill, such that oil released from the incident on one unit will not expose an adjacent unit.

6-5.8

Water drainage from areas that might contain radioactivity shall be collected, sampled, and analyzed before discharge to the environment.

6-5.9

Water released during fire suppression operations in areas containing radioactivity shall be drained to a location that would be acceptable for the containment of radioactive materials.

6-6 Emergency Lighting.

6-6.1

Emergency lighting units shall provide adequate lighting levels. The lighting units shall be sized to provide a duration of operation that will adequately illuminate the egress and access routes to areas containing safe shutdown equipment and the equipment operation until normal or emergency plant lighting can be re-established.

6-6.2

The illumination of means of egress shall be in accordance with NFPA *101, Life Safety Code*. The illumination shall include emergency lighting and marking of the means of egress.

6-6.3

The floor of the means of egress and the safe shutdown operations shall be illuminated at all points including angles, intersections of corridors, passageways, stairways, landings of stairways, exit doors, safe shutdown equipment, and access and egress routes to safe shutdown equipment to values of not less than 1 foot-candle measured at the floor and at safe shutdown equipment.

6-6.4

The required illumination shall be so arranged that the failure of any single lighting unit, such as the burning out of a single light bulb, will not leave any area in darkness.

6-6.5

Suitable battery-powered hand lights shall be provided for emergency use by the fire brigade and other operations personnel required to achieve safe plant shutdown.

6-7 Lightning Protection.

The plant shall be provided with a lightning protection system in accordance with NFPA 780, *Standard for the Installation of Lightning Protection Systems*.

6-8 Electrical Cabling.

6-8.1

As a minimum, combustible cable insulation and jacketing material shall meet the fire and flame test requirements of IEEE 383, *Standard for Type Test of Class IE Electric Cables, Field Splices and Connections for Nuclear Power Generating Stations*. Meeting the requirements of IEEE 383 shall not eliminate the need for protection as specified in this standard and the fire hazards analysis.

6-8.2

Fiber optic cable insulation and jacketing material shall meet the fire and flame test requirements of IEEE 383, *Standard for Type Test of Class IE Electric Cables, Field Splices and Connections for Nuclear Power Generating Stations*.

6-8.3

Group cabling shall be routed away from exposure hazards or protected as specified in this standard. Specifically, group cabling shall not be routed near sources of ignition or flammable and combustible liquid hazards.

6-8.4

Cable raceways shall be used only for cables.

6-8.5

Only metal shall be used for cable trays.

6-8.6

Only metallic tubing shall be used for conduit.

Exception: Nonmetallic conduit shall be permitted to be used with concrete encasement or for direct burial runs.

6-8.6.1 Thin-wall metallic tubing shall not be used.

6-8.6.2 Flexible metallic tubing shall only be used in lengths less than 5 ft (1.5 m) to connect components to equipment.

6-8.6.3 Other raceways shall be made of noncombustible materials.

6-9* Exposure Protection.

Buildings shall be protected from exposure fires by any one of the following:

(a) A listed 3-hr fire barrier with automatic or self-closing fire doors having a fire protection rating of 3 hr and listed penetration protection of 3-hr rating,

(b) A spatial separation of at least 50 ft (15.2 m), or

(c) Exterior exposure protection.

6-10 Electrical Systems for the Plant.

The electrical design and installation of electrical generating, control, transmission, distribution, and metering of electrical energy shall be provided in accordance with NFPA 70, *National Electrical Code*, or ANSI C2, *National Electrical Safety Code*, as applicable.

6-11 Communications.

6-11.1

The plant-approved voice/alarm communication system in accordance with NFPA 72, *National Fire Alarm Code*, shall be available on a priority basis for fire announcements, directing plant fire brigade, and fire evacuation announcements.

6-11.2*

A portable radio communication system shall be provided for use by the fire brigade and other operation personnel required to achieve safe shutdown.

6-11.3

The radio communication system shall not interfere with the communication capabilities of the plant security force.

6-11.4

The impact of fire damage on the communication systems shall be considered when installing fixed repeaters to permit the use of portable radios. Repeaters shall be located such that a fire-induced failure of the repeater will not also cause failure of the other communication systems relied upon for safe shutdown.

6-11.5*

Plant control equipment shall be designed so that the control equipment is not susceptible to radio frequency interferences from portable radios.

6-11.6

Preoperational tests and periodic testing shall demonstrate that the frequencies used for portable radio communications will not affect actuation of protective relays or other electrical components.

Chapter 7 General Fire Protection Systems and Equipment

7-1 General.

7-1.1*

A fire hazards analysis shall be conducted to determine the fire protection requirements for the facility.

7-1.2*

All fire protection systems, equipment, and installations shall be dedicated to fire protection purposes.

Exception No. 1: Except when in accordance with 7-4.9.

Exception No. 2: Fire protection systems shall be permitted to be used to provide redundant backup to nuclear-safety systems provided the fire protection systems meet the design basis requirements of the nuclear-safety systems. Fire protection systems used in this manner shall be designed to handle both functions.

7-1.3

All fire protection equipment shall be listed or approved for its intended service.

7-2 Water Supply.

7-2.1*

The fire water supply shall be calculated on the basis of the largest expected flow rate for a period of 2 hr, but shall not be less than 300,000 gal (1 135 500 L). This flow rate shall be based on 500 gal/min (1892.5 L/min) for manual hose streams plus the largest design demand of any sprinkler or fixed water spray system as determined in accordance with this standard, NFPA 13, *Standard for the Installation of Sprinkler Systems*, or NFPA 15, *Standard for Water Spray Fixed Systems for Fire Protection*. The fire water supply shall be capable of delivering this design demand with the hydraulically least demanding portion of fire main loop out of service.

7-2.2*

Two 100 percent [minimum of 300,000 gal (1 135 500 L) each] system capacity tanks shall be installed. The tanks shall be interconnected such that fire pumps can take suction from either or both. A failure in one tank or its piping shall not cause both tanks to drain. The tanks shall be designed in accordance with NFPA 22, *Standard for Water Tanks for Private Fire Protection*.

Exception: Refill times for filling the water tanks do not apply.

7-2.3*

The tanks shall not be supplied by an untreated, raw water source.

7-2.4 Fire Pumps.

7-2.4.1 Fire pumps shall meet the requirements of NFPA 20, *Standard for the Installation of Centrifugal Fire Pumps*, and shall be automatic starting.

7-2.4.2* Fire pumps shall be provided to ensure that 100 percent of the flow rate capacity will be available assuming failure of the largest pump.

7-2.4.3 Individual fire pump connections to the yard fire main loop shall be separated with sectionalizing valves between connections. Each pump and its driver and controls shall be located in a room separated from the remaining fire pumps by a fire wall with a minimum rating of 3 hr. The fuel for the diesel fire pump(s) shall be separated so that it does not provide a fire source exposing safety-related equipment.

7-2.4.4 A method of automatic pressure maintenance of the fire protection system shall be provided independent of the fire pumps.

7-2.4.5 Supervisory signals and visible indicators required by NFPA 20 shall be received in the control room.

7-3 Valve Supervision.

All fire protection water supply and system control valves shall be under a periodic inspection program (*see Chapter 3*) and shall be supervised by one of the following methods:

(a) Electrical supervision with audible and visual signals in the main control room or another constantly attended location and monthly valve inspections;

(b) Locking valves in their normal position and monthly valve inspections. Keys shall be made available only to authorized personnel; or

(c) Sealing valves in their normal positions and weekly valve inspections. This option shall be utilized only where valves are located within fenced areas or under the direct control of the property owner.

7-4 Yard Mains, Hydrants, and Building Standpipes.

7-4.1

The underground yard fire main loop shall be installed to furnish anticipated water requirements. NFPA 24, *Standard for the Installation of Private Fire Service Mains and Their Appurtenances*, gives necessary guidance for such installation. It references other design codes and standards developed by such organizations as the American National Standards Institute (ANSI) and the American Water Works Association (AWWA). The type of pipe and water treatment shall be design considerations, with tuberculation as one of the parameters. Means for inspecting and flushing the systems shall be provided.

7-4.2

Approved visually indicating sectional control valves such as post-indicator valves shall be provided to isolate portions of the main for maintenance or repair without simultaneously shutting off the supply to both primary and backup fire suppression systems.

7-4.3

Valves shall be installed to permit isolation of outside hydrants from the fire main for maintenance or repair without interrupting the water supply to automatic or manual fire suppression systems.

7-4.4

A common yard fire main loop may serve multi-unit nuclear power plant sites if it is cross-connected between units. Sectional control valves shall permit maintaining independence of the individual loop around each unit. For such installations, common water supplies shall also be permitted to be utilized. For multiple-reactor sites with widely separated plants [approaching 1 mi. (1.6 km) or more], separate yard fire main loops shall be used.

7-4.5

Outside manual hose installation shall be sufficient to provide an effective hose stream to any on-site location. Hydrants with individual hose gate valves shall be installed approximately every 250 ft (76 m) apart on the yard main system. A hose house equipped with hose and combination nozzle and other auxiliary equipment specified in NFPA 24, *Standard for the Installation of Private Fire Service Mains and Their Appurtenances*, shall be provided at intervals of not more than 1000 ft (305 m) along the yard main system.

Exception: Mobile means of providing hose and associated equipment, such as hose carts or trucks, shall be permitted in lieu of hose houses. Where provided, such mobile equipment shall *be equivalent to the equipment supplied by three hose houses.*

7-4.6

Threads compatible with those used by local fire departments shall be provided on all hydrants, hose couplings, and standpipe risers, or the fire departments shall be provided with adapters that allow interconnection between plant equipment and the fire department equipment.

7-4.7

Sprinkler systems and manual hose station standpipes shall have connections to the plant underground water main so that a single active failure or a crack in a moderate-energy line can be isolated so as not to impair both the primary and backup fire suppression systems. Alternatively, headers fed from each end are permitted inside buildings to supply both sprinkler and standpipe systems, provided steel piping and fittings meeting the requirements of ANSI B31.1, *Code for Power Piping*, are used for the headers (up to and including the first valve) supplying the sprinkler systems where such headers are part of the seismically analyzed hose standpipe system. Where provided, such headers are considered an extension of the yard main system. Each sprinkler and standpipe system shall be equipped with an outside screw and yoke (OS&Y) gate valve or other approved shutoff valve.

7-4.8

For all power block buildings, Class III standpipe and hose systems shall be installed in accordance with NFPA 14, *Standard for the Installation of Standpipe and Hose Systems*. For all other buildings on site, the requirements for standpipe and hose systems shall be appropriate for the hazard being protected.

7-4.9*

The proper type of hose nozzle to be supplied to each area shall be based on the fire hazards analysis. The usual combination spray/straight-stream nozzle shall not be used in areas where the straight stream can cause unacceptable damage. Approved, electrically safe fixed fog nozzles shall be provided at locations where high-voltage shock hazards exist. All hose nozzles shall have shutoff capability.

7-4.10 Seismic Fire Suppression Capabilities.

7-4.10.1* Provisions shall be made to supply water at least to standpipes and hose stations for manual fire suppression in all areas containing nuclear-safety-related systems and components for safe shutdown in the event of a safe shutdown earthquake (SSE).

7-4.10.2 The piping system serving these hose stations shall be analyzed for safe shutdown and earthquake loading, and shall be provided with supports that ensure pressure boundary integrity. The piping and valves for the portion of hose standpipe system affected by this functional requirement shall, as a minimum, satisfy the requirements of ANSI B31.1, *Code for Power Piping*.

7-4.10.3 The system shall be designed to flow a minimum of one Class III standpipe station in accordance with NFPA 14, *Standard for the Installation of Standpipe and Hose Systems*.

7-4.10.4 Where the seismic required hose stations are cross-connected to essential seismic Category I water systems, the fire flow shall not degrade the essential water system requirements.

7-5 Portable Fire Extinguishers.

7-5.1

Portable and wheeled fire extinguishers shall be installed, inspected, maintained, and tested in accordance with NFPA 10, *Standard for Portable Fire Extinguishers*.

Exception: Where placement of extinguishers would result in required activities that are contrary to personnel radiological exposure concerns or nuclear-safety-related concerns, fire extinguishers shall be permitted to be inspected at intervals greater than those specified in NFPA 10, Standard on Portable Fire Extinguishers, or consideration shall be given to locating the extinguishers outside high radiation areas.

7-6 Fire Suppression Systems.

7-6.1

Automatic suppression systems shall be provided in all areas of the plant as required by the fire hazards analysis. Except as modified in this chapter, the following NFPA standards shall be used:

(a) NFPA 11, *Standard for Low-Expansion Foam;*

(b) NFPA 11A, *Standard for Medium- and High-Expansion Foam Systems;*

(c) NFPA 12, *Standard on Carbon Dioxide Extinguishing Systems;*

(d) NFPA 13, *Standard for the Installation of Sprinkler Systems;*

(e) NFPA 15, *Standard for Water Spray Fixed Systems for Fire Protection;*

(f) NFPA 16, *Standard on the Installation of Deluge Foam-Water Sprinkler and Foam-Water Spray Systems;*

(g) NFPA 17, *Standard for Dry Chemical Extinguishing Systems*;

(h) NFPA 214, *Standard on Water-Cooling Towers*; and

(i) NFPA 2001, *Standard on Clean Agent Fire Extinguishing Systems*.

7-6.2

The extinguishing systems chosen shall be based upon the design parameters required as a result of the fire hazards analysis.

7-6.3

Selection of extinguishing agent shall be based upon:

(a) Type or class of hazard;

(b) Effect of agent discharge on critical equipment such as thermal shock, continued operability, water damage, overpressurization, cleanup, etc.; and

(c) Health hazards.

7-6.4

Each fire suppression system shall be equipped with approved alarming devices and annunciate in a constantly attended area.

7-7 Fire Alarm Systems.

7-7.1

Fire signaling systems shall be provided in all areas of the plant as required by the fire hazards analysis. The requirements of this chapter constitute the minimum acceptable protective signaling system functions when used in conjunction with NFPA 72, *National Fire Alarm Code*.

7-7.2*

The signaling system's initiating device and signaling line circuits shall provide emergency operation for fire detection, fire alarm, and water flow alarm during a single break or a single ground fault.

7-7.3

The fire signaling equipment used for fixed fire suppression systems shall give audible and visual alarm and system trouble annunciation in the plant control room for the power block buildings. Local alarm shall be provided. Other fire alarm signals from other buildings shall be permitted to annunciate at the control room or other locations that are constantly attended.

7-7.4*

Audible signaling appliances shall produce a distinctive sound, used for no other purpose. (*See NFPA 72, National Fire Alarm Code*.) Audible signaling devices shall be located and installed so that the alarm can be heard above ambient noise levels.

7-7.5

Plant control room or plant security personnel shall be trained in the operation of all fire signaling systems used in the plant. This training shall include the ability to identify any alarm zone or fire protection system that is operating.

7-7.6

Fire signaling equipment and actuation equipment for the release of fixed fire suppression systems shall be connected to power supply sources in accordance with the requirements of NFPA 72, *National Fire Alarm Code*, and shall be routed outside the area to be protected.

7-7.7

Manual fire alarm boxes shall be installed as required by the fire hazards analysis. (*See NFPA 72, National Fire Alarm Code*.) Where manual release devices are installed for the purpose of releasing an extinguishing agent in a fixed fire suppression system, the manual releases shall be clearly marked for that purpose. The manual release device circuits shall be routed outside the area protected by the fixed extinguishing system.

7-7.8

All signals shall be permanently recorded in accordance with NFPA 72, *National Fire Alarm Code*.

7-8 Fire Detectors.

Automatic fire detectors shall be selected and installed in accordance with:

(a) NFPA 72, *National Fire Alarm Code*;

(b) The design parameters required as a result of the fire hazards analysis of the plant area; and

(c) The additional requirements of this standard.

Chapter 8 Identification of and Protection Against Hazards

8-1* General.

The identification and selection of fire protection systems shall be based on the fire hazards analysis. This chapter identifies fire and explosion hazards in advanced light water reactor plants and specifies the protection criteria that shall be used unless the fire hazards analysis indicates otherwise.

8-2 Primary and Secondary Containments.

8-2.1 Normal Operation.

Fire protection for the primary and secondary containment areas shall be provided for hazards identified by the fire hazards analysis.

8-2.1.1 Operation of the fire protection systems shall not compromise the integrity of the containment or other safety-related systems. Fire protection systems in the containment areas shall function in conjunction with total containment requirements such as ventilation and control of containment liquid and gaseous release.

8-2.1.2 Inside primary containment, fire detection systems shall be provided for each fire hazard identified in the fire hazards analysis. The type of detection used and the location of the detectors shall be the most suitable for the particular type of fire hazard identified by the fire hazards analysis.

8-2.1.3 A general area fire detection capability shall be provided in the primary containment as a backup for the hazard detection described above. To accomplish this, suitable smoke or heat detectors compatible with the radiation environment shall be installed in accordance with NFPA 72, *National Fire Alarm Code*.

8-2.1.4 Standpipe and hose stations shall be installed inside containment. Standpipe and hose stations inside containment shall be permitted to be connected to a high quality water supply of sufficient quantity and pressure other than the fire main loop if plant-specific features prevent extending the fire main supply inside containment.

Exception: For inerted primary containment, standpipe and hose stations shall be permitted to be placed outside the primary containment, with hose no longer than 100 ft (30.5 m), to reach any location inside the primary containment with a 30-ft (9.1-m) effective hose stream.

8-2.1.5 Reactor coolant pumps with an external lubrication system shall be provided with an oil collection system. The oil collection system shall be so designed, engineered, and installed that failure of the oil collection system will not lead to a fire during normal operations, or off-normal conditions such as accident conditions, or earthquakes.

8-2.1.6 The oil collection systems shall be capable of collecting oil from all potential pressurized and unpressurized leakage sites in the reactor coolant pump oil systems. Leakage shall be collected and drained to a vented closed container that can hold the entire oil system inventory.

A flame arrester is required in the vent if the flash point characteristics of the oil present the hazard of fire flashback. Leakage points to be protected shall include the lift pump and piping, overflow lines, oil cooler, oil fill and drain lines and plugs, flanged connections on oil lines, and oil reservoirs where such features exist on the reactor coolant pumps. The drain line shall be large enough to accommodate the largest potential oil leak.

8-2.2 Refueling and Maintenance.

8-2.2.1* Management procedures and controls necessary to ensure adequate fire protection for fire hazards introduced during maintenance and refueling shall be provided. Adequate backup fire suppression shall be provide so that total reliance is not placed on a single fire suppression system.

8-2.2.2 Adequate self-contained breathing apparatus shall be provided near the containment entrance for fire-fighting and damage control personnel. These units shall be independent of any breathing apparatus or air supply systems provided for general plant activities and shall be clearly marked as emergency equipment.

8-3 Control Room Complex.

8-3.1

The control room complex (including kitchen, office spaces, etc.) shall be protected against disabling fire damage and shall be separated from other areas of the plant by floors, walls, ceilings, and roofs having a minimum fire resistance rating of 3 hr. Peripheral rooms in the control room complex shall have an automatic water-based suppression system, where required by the fire hazards analysis, and shall be separated from the control room by noncombustible construction with a minimum fire resistance rating of 1 hr. Ventilation system openings between the control room and the peripheral rooms shall have automatic smoke dampers installed that close on operation of the fire detection and fire suppression systems.

8-3.2

Manual fire-fighting capability shall be provided for both:

(a) Fires originating within a cabinet, console, or connecting cables; and

(b) Exposure fires involving combustibles in the general room area.

8-3.3

Portable Class A and Class C fire extinguishers shall be located in the control room. A fire hose station shall be installed immediately outside of the control room.

8-3.4

Nozzles that are compatible with the hazards and the equipment in the control room shall be provided for the fire hose stations. The choice of nozzles shall satisfy fire-fighting requirements and electrical safety requirements, and shall minimize physical damage to electrical equipment from hose stream impingement.

8-3.5

Smoke detectors shall be provided in the control room complex, the electrical cabinets, and consoles. If redundant safe shutdown equipment is located in the same control room cabinet or console, the cabinet or console shall be provided with internal separation (noncombustible barriers) to limit the damage to one safety division.

8-3.6

Breathing apparatus for the control room operators shall be readily available.

8-3.7

The outside air intakes for the control room ventilation system shall be provided with smoke detection capability to alarm in the control room and enable manual isolation of the control room ventilation system, thus preventing smoke from entering the control room.

8-3.8

Venting of smoke produced by a fire in the control room by means of the normal ventilation system is acceptable; however, provision shall be made to permit isolation of the recirculation portion of the normal ventilation system. Manually operated venting of the control room shall be available to the operators.

8-3.9

All cables that enter the control room shall terminate in the control room. No cabling shall be routed through the control room from one area to another. Cables in spaces underfloor and in above-ceiling spaces shall meet the separation criteria necessary for fire protection.

8-3.10

Air-handling functions shall be ducted separately from cable runs in such spaces (i.e., if cables are routed in underfloor or ceiling spaces, these spaces shall not be used as air plenums for ventilation of the control room). Fully enclosed electrical raceways located in such underfloor and ceiling spaces, if over 1 ft^3 (0.09 m^2) in cross-sectional area, shall have automatic fire suppression inside. Area automatic fire suppression shall be provided for underfloor and ceiling spaces if used for cable runs unless all cable is run in 4-in. (101.6-mm) or smaller steel conduit or cables are in fully enclosed raceways internally protected by automatic fire suppression.

8-4 Cable Concentrations.

8-4.1 Cable Spreading Room.

8-4.1.1 The cable spreading room shall have an automatic water-based suppression system. The location of sprinklers or spray nozzles shall consider cable tray arrangements to ensure adequate water coverage for areas that could present exposure fire hazards to the cable raceways. Automatic sprinkler systems shall be designed for a density of 0.30 gal/min/ft^2 (12.2 L/min/m^2) over the most remote 2500 ft^2 (232.2 m^2).

8-4.1.2 Suppression systems shall be zoned to limit the area of protection to that which the drainage system can handle with any two adjacent systems actuated. Deluge and water spray systems shall be hydraulically designed with each zone calculated with the largest adjacent zone flowing.

8-4.1.3 Cable spreading rooms shall have:

(a) At least two remote and separate entrances for access by the fire brigade personnel,

(b) An aisle separation between tray stacks at least 3 ft (0.9 m) wide and 8 ft (24 m) high,

(c) Hose stations and portable fire extinguishers installed immediately outside the room, and (d)* Area smoke detection.

8-4.2 Cable Tunnels.

8-4.2.1* **Detection Systems.** Cable tunnels shall be provided with smoke detection.

8-4.2.2 Suppression Systems.

8-4.2.2.1 Cable tunnels shall be provided with automatic fixed suppression systems. Automatic sprinkler systems shall be designed for a density of 0.30 gal/min/ft^2 (12.2 L/min/m^2) for the most remote 100 linear ft (30.5 m) of cable tunnel up to the most remote 2500 ft^2 (232.2 m^2).

8-4.2.2.2 The location of sprinklers or spray nozzles shall consider cable tray arrangements and possible transient combustibles to ensure adequate water coverage for areas that could present exposure fire hazards to the cable raceways.

8-4.2.2.3 Deluge sprinkler systems or deluge spray systems shall be zoned to limit the area of protection to that which the drainage system can handle with any two adjacent systems actuated. The systems shall be hydraulically designed with each zone calculated with the largest adjacent zone flowing.

8-4.2.3 Cables shall be designed to allow wetting undamaged cables with water supplied by the fire suppression system without electrical faulting.

8-4.2.4 Cable tunnels over 50 ft (15.2 m) long shall have:

(a) At least two remote and separate entrances for access by the fire brigade personnel,

(b) An aisle separation between tray stacks at least 3 ft (0.9 m) wide and 8 ft (2.4 m) high, and

(c) Hose stations and portable fire extinguishers installed immediately outside the tunnel.

8-4.3 Cable Shafts and Risers.

Cable tray fire breaks shall be installed every 20 ft (6.1 m) for vertical cable trays that rise over 30 ft (9.1 m). Access to cable shafts shall be provided every 40 ft (12.2 m) with the topmost access within 20 ft (6.1 m) of the cable shaft ceiling. Automatic sprinkler protection and smoke detection shall be provided at the ceiling of the vertical shaft.

8-5 Plant Computer and Communication Rooms.

Computer and communication rooms shall meet the applicable requirements of NFPA 75, *Standard for the Protection of Electronic Computer/Data Processing Equipment*.

8-6 Switchgear Rooms and Relay Rooms.

8-6.1*

Smoke detection shall be provided and shall alarm in both the control room and locally. Cables entering the safety-related switchgear rooms shall terminate in the switchgear room. The safety-related switchgear rooms shall not be used for other purposes. Fire hose stations and portable fire extinguishers shall be readily available outside the area.

8-6.2

Equipment shall be located to facilitate fire fighting. Drains shall be provided to prevent water accumulation from damaging safety-related equipment. Remote manually actuated ventilation shall be provided for smoke removal when manual fire suppression is needed. (*See Section 6-4*.)

8-7 Battery Rooms.

8-7.1*

Battery rooms shall be provided with ventilation to limit the concentration of hydrogen to 2 percent by volume. Loss of ventilation shall alarm in the control room.

8-7.2

Safety-related battery rooms shall be protected against fires and explosions. Battery rooms shall be separated from other areas of the plant by fire barriers having a 1-hr minimum rating. Direct current switchgear and inverters shall not be located in these battery rooms. Fire detection shall be provided. Fire hose stations and portable fire extinguishers shall be readily available outside the room.

8-8 Turbine Building.

8-8.1*

The turbine building shall be separated from adjacent structures containing safety-related equipment by fire-resistive barriers having a minimum 3-hr rating. The fire barriers shall be designed so that the barrier will remain in place even in the event of a complete collapse of the turbine structure. Openings and penetrations shall be minimized in the fire barrier and shall not be located where turbine oil systems or generator hydrogen cooling systems create a direct fire exposure hazard to the fire barrier. Smoke and heat removal systems shall be provided in accordance with 6-4.3.

Exception: For those plants provided with complete automatic sprinkler protection at the roof level, smoke and heat removal systems are not required.

8-8.2 Beneath Turbine Generator Operating Floor.

8-8.2.1* All areas beneath the turbine generator operating floor shall be protected by an automatic sprinkler or foam-water sprinkler system. The sprinkler system beneath the turbine generator shall take into consideration obstructions from structural members and piping and shall be designed to a minimum density of 0.30 gal/min/ft^2 (12.2 L/min/m^2) over a minimum application of 5000 ft^2 (464.5 m^2).

8-8.2.2 Foam-water sprinkler systems installed in place of automatic sprinklers described above shall be designed in accordance with NFPA 16, *Standard on the Installation of Deluge Foam-Water Sprinkler and Foam-Water Spray Systems*, or NFPA 16A, *Standard for the Installation of Closed-Head Foam-Water Sprinkler Systems*, and the design densities specified above.

8-8.2.3 Electrical equipment in the area covered by a water or foam system shall be of the enclosed type or otherwise protected to minimize water damage in the event of system operation.

8-8.3* Turbine Generator Bearings.

8-8.3.1 Automatic fixed suppression systems shall be provided for all turbine generator and exciter bearings. If closed-head water spray systems utilizing directional nozzles in accordance with NFPA 15, *Standard for Water Spray Fixed Systems for Fire Protection*, are provided, bearing protection shall be provided for a minimum density of 0.30 gal/min/ft^2 (12.2 L/min/m^2) over the protected area.

8-8.3.2 Accidental water discharge on bearing points and hot turbine parts shall be considered. If necessary, these areas shall be permitted to be protected by shields and encasing insulation with metal covers.

8-8.4

Lubricating oil lines above the turbine operating floor shall be protected with an automatic sprinkler system covering those areas subject to oil accumulation, including the area within the turbine lagging (skirt). The automatic sprinkler system shall be designed to a minimum density of 0.30 gal/min/ft^2 (12.2 L/min/m^2).

8-8.5

Lubricating oil reservoirs and handling equipment shall be protected in accordance with 8-8.2.1. If the lubricating oil reservoir is elevated, sprinkler protection shall be extended to protect the area beneath the reservoir.

8-8.6

If shaft-driven ventilation systems are not used, the area inside a directly connected exciter housing shall be protected with an automatic fire suppression system. If shaft-driven ventilation systems are used, an automatic preaction sprinkler system providing a density of 0.30 gal/min/ft^2 (12.2 L/min/m^2) over the entire area shall be provided.

8-8.7

Clean or dirty oil storage areas shall be protected based on the fire risk evaluation. This area generally represents the largest concentrated oil storage area in the plant. The designer shall consider, as a minimum, the installation of fixed automatic fire protection systems and the ventilation and drainage requirements in Chapter 6.

8-8.8 Hydrogen Systems.

8-8.8.1 General.

8-8.8.1.1 For hydrogen storage systems, see NFPA 50A, *Standard for Gaseous Hydrogen Systems at Consumer Sites*, or NFPA 50B, *Standard for Liquefied Hydrogen Systems at Consumer Sites*.

8-8.8.1.2 Bulk hydrogen systems supplying one or more generators shall have automatic valves located at the supply and operable by “dead man”-type controls at the generator fill point(s) or operable from the control room. This will minimize the potential for a major discharge of hydrogen in the event of a leak from piping inside the plant. Alternatively, vented guard piping shall be permitted to be used inside the building to protect runs of hydrogen piping.

8-8.8.1.3 A flanged spool piece or equivalent arrangement shall be provided to facilitate the separation of hydrogen supply when the generator is open for maintenance.

8-8.8.1.4 For electrical equipment in the vicinity of the hydrogen handling equipment, including detraining equipment, seal oil pumps, valves etc., see Article 500 of NFPA 70, *National Electrical Code*, and Section 127 of ANSI C2, *National Electrical Safety Code*.

8-8.8.1.5 Control room alarms shall be provided to indicate abnormal gas pressure, temperature, and percentage of hydrogen in the generator.

8-8.8.1.6 The generator hydrogen dump valve and hydrogen detraining equipment shall be arranged to vent directly to a safe outside location. The dump valve shall be remotely operable from the control room or from an area accessible during a machine fire.

8-8.8.1.7* An excess-flow check valve shall be provided for the bulk supply hydrogen piping.

8-8.8.2 Hydrogen Seal Oil Pumps.

8-8.8.2.1 Redundant hydrogen seal oil pumps with separate power supplies shall be provided for adequate reliability of seal oil supply.

8-8.8.2.2 Where feasible, electrical circuits to redundant pumps shall be run in buried conduit or provided with fire-retardant coating if exposed in the area of the turbine generator to minimize the possibility of loss of both pumps as a result of a turbine generator fire.

8-8.8.2.3 Hydrogen seal oil units shall be protected in accordance with 8-8.2. Hydrogen seal oil units shall be protected by an automatic, open-head water spray system providing a density of 0.30 gal/min (1.13 L/min) over the hydrogen seal area.

8-8.8.2.4 Curbing or drainage or both shall be provided for the hydrogen seal oil unit in accordance with Section 6-5.

8-8.8.3 Hydrogen in Safety-Related Areas.

8-8.8.3.1 Hydrogen lines in safety-related areas shall be either designed to seismic Class I requirements or sleeved such that the outer pipe is directly vented to the outside, or shall be equipped with excess-flow valves so that, in case of a line break, the hydrogen concentration in the affected areas will not exceed 2 percent.

8-8.8.3.2 Hydrogen lines or sensing lines containing hydrogen shall not be piped into or through the control room.

8-8.9 Hydraulic Control Systems.

The hydraulic control system shall use a listed fire-resistant fluid.

8-8.10* Lubricating Oil Systems.

8-8.10.1 Turbine lubricating oil reservoirs shall be provided with vapor extractors, which shall be vented to a safe outside location.

8-8.10.2 Curbing or drainage or both shall be provided for the turbine lubricating oil reservoir in accordance with Section 6-5.

8-8.10.3 All oil pipe serving the turbine generator shall be designed and installed to minimize the possibility of an oil fire in the event of severe turbine vibration.

8-8.10.4* Piping design and installation shall consider the following measures:

(a) Welded construction,

(b) Guard pipe construction with the pressure feed line located inside the return line or in a separate shield pipe drained to the oil reservoir,

(c) Route oil piping clear of or below steam piping or metal parts, and

(d) Insulate with impervious lagging for steam piping or hot metal parts under or near oil piping or turbine bearing points.

8-8.10.5 Cable for operation of the lube oil pumps shall be protected from fire exposure. Where feasible, electrical circuits to redundant pumps shall be run in buried conduit. Protection shall be permitted to consist of separation of cables for ac and dc oil pumps or 1-hr fire-resistive coating (derating of cable shall be considered).

8-9 Standby Emergency Diesel Generators and Combustion Turbines.

8-9.1

The installation and operation of standby emergency diesel generators and combustion turbines shall be in accordance with NFPA 37, *Standard for the Installation and Use of Stationary Combustion Engines and Gas Turbines*.

Exception: Automatic shutdown and remote shutdown features, which shall be governed by nuclear-safety requirements.

8-9.2

Standby emergency diesel generators and combustion turbines located within main plant structures shall be protected by automatic sprinkler, water spray, or foam-water sprinkler systems. Sprinkler and water spray protection systems shall be designed for a 0.25-gal/min/ft^2 (10.19-L/min/m^2) density over the entire area.

8-9.3

Fire detection shall be provided to alarm and annunciate in the control room and to alarm locally. Fire hose stations and portable fire extinguishers shall be readily available outside the area. Drainage for fire-fighting water and means for local manual venting of smoke shall be provided.

8-9.4

A day tank is permitted in standby emergency diesel generator and combustion turbine rooms if the day tank is located in a diked enclosure that has sufficient capacity to hold 110 percent of the contents of the day tank or is drained to a safe location.

8-10 Diesel Fuel Storage and Transfer Areas.

8-10.1

Diesel fuel oil storage tanks shall not be located inside buildings containing other nuclear-safety-related equipment. If aboveground tanks are used, they shall be located at least 50 ft (15.2 m) from any building, or if within 50 ft (15.2 m), they shall be separated from the building by a fire barrier having a minimum 3-hr rating. Potential oil spills shall be confined or directed away from buildings containing safety-related equipment. Underground tanks are acceptable outside or under buildings. (*See NFPA 30 for additional guidance*.)

8-10.2

Aboveground tanks shall be provided with automatic fire suppression systems.

8-11 Nuclear-Safety-Related Pump Rooms.

These rooms shall be protected by fire detection systems. Automatic fire suppression systems shall be provided unless the fire hazards analysis determines that fire suppression is not required.

Fire hose stations and fire extinguishers shall be readily accessible.

8-12 New Fuel Area.

8-12.1

Fire extinguishers shall be located within the new fuel area. Fire hose stations shall be located as determined by the fire hazards analysis to facilitate access and use for fire-fighting operations. Fire detection systems shall be provided. Combustible material shall be limited to the minimum necessary for operation in the new fuel area.

8-12.2

The storage configuration of new fuel shall always be maintained as to preclude criticality for any water density that might occur during fire water application.

8-13 Spent Fuel Pool Area.

Protection for the spent fuel pool area shall be provided by fire hose stations and fire extinguishers. Fire detection shall be provided in the area.

8-14 Rad Waste and Decontamination Areas.

Fire barriers, fire detection, and automatic fire suppression shall be provided as determined by the fire hazards analysis. Manual ventilation control to assist in smoke removal shall be provided if necessary for manual fire fighting.

8-15 Safety-Related Water Tanks.

Storage tanks that supply water for fire-safe shutdown shall be protected from the effects of an exposure fire. Combustible materials shall not be stored next to these tanks.

8-16 Record Storage Areas.

Record storage areas shall be located and protected in accordance with NFPA 232, *Standard for the Protection of Records*. Record storage areas shall not be located in safety-related areas and shall be separated from safety-related areas by fire barriers having a minimum 3-hr rating.

8-17 Cooling Towers.

Cooling towers shall be of noncombustible or limited-combustible construction and located such that a fire in the cooling tower will not adversely affect safety-related systems or equipment. Cooling towers shall be of noncombustible construction when the basin is used as the ultimate heat sink.

Exception: If combustible construction is used, the cooling towers shall be protected by automatic sprinklers or water spray systems in accordance with NFPA 214, Standard on Water Cooling Towers, and shall be located so that they do not affect safety-related systems or equipment in the event of a fire.

8-18 Acetylene-Oxygen Fuel Gases.

Gas cylinder storage locations or the fire protection systems that serve those safety-related areas shall not be in areas that contain or expose safety-related equipment.

8-19 Storage Areas for Ion Exchange Resins.

Unused ion exchange resins shall not be stored in areas that contain or expose safety-related systems or equipment.

8-20 Storage Areas for Hazardous Chemicals.

Hazardous chemicals shall not be stored in areas that contain or expose safety-related systems or equipment.

8-21 Warehouses.

Automatic sprinkler protection shall be provided for warehouses that contain high-value equipment or combustible materials.

8-22 Fire Pump Room/House.

Rooms housing diesel-driven fire pumps shall be protected by automatic sprinkler, water spray, or foam-water sprinkler systems. If sprinkler and water spray systems are provided for fire pump houses, they shall be designed for a minimum density of 0.25 gal/min/ft^2 (10.19 L/min/m^2) over the entire fire area.

8-23 Transformers.

8-23.1

Buildings shall be protected from exposure fires involving oil-filled transformers by locating the transformer casing, conservator tank, and cooling radiators at least 50 ft (15.2 m) from buildings or by providing a minimum 2-hr fire barrier between transformers and exposed buildings [*see Figures 8-23.1(a) and (b)*]. A minimum 1-hr fire barrier or a distance of 30 ft (9.1 m) shall be provided between adjacent transformers. Means shall be provided to contain oil spills.

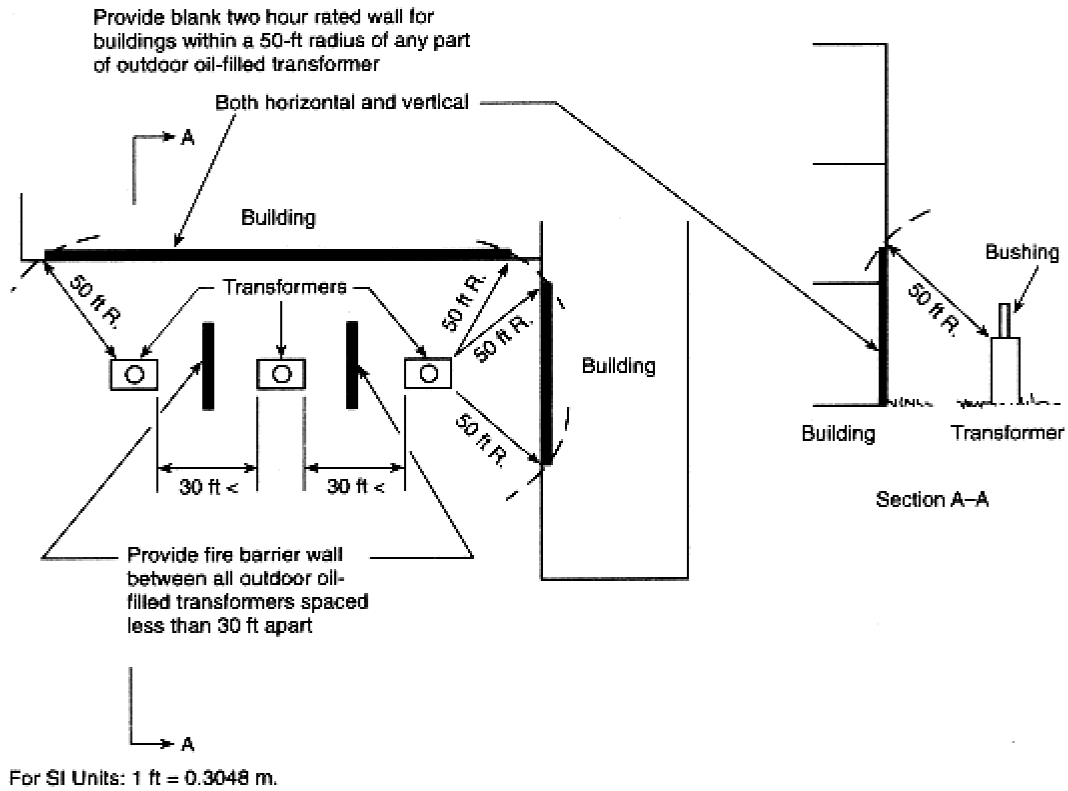
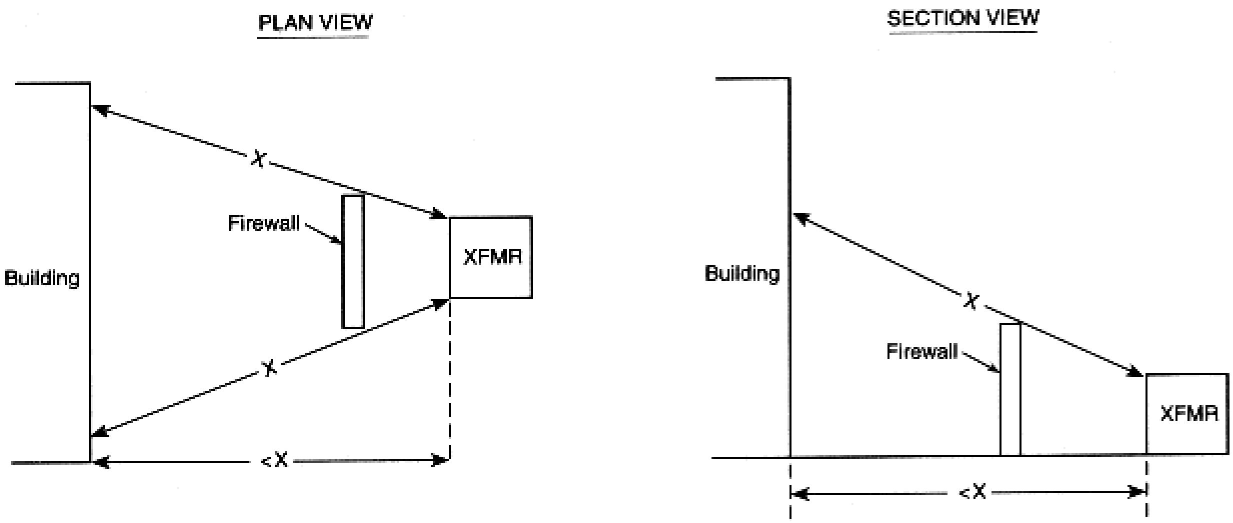
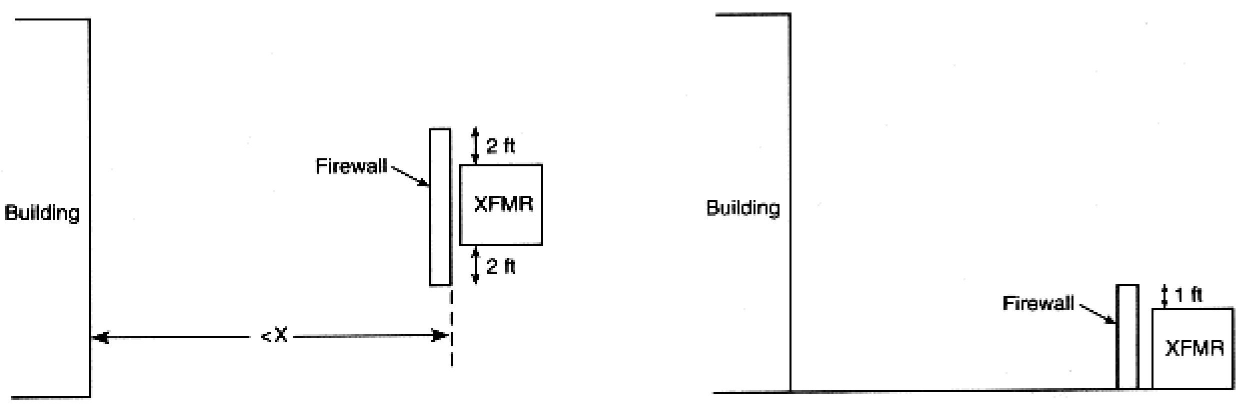


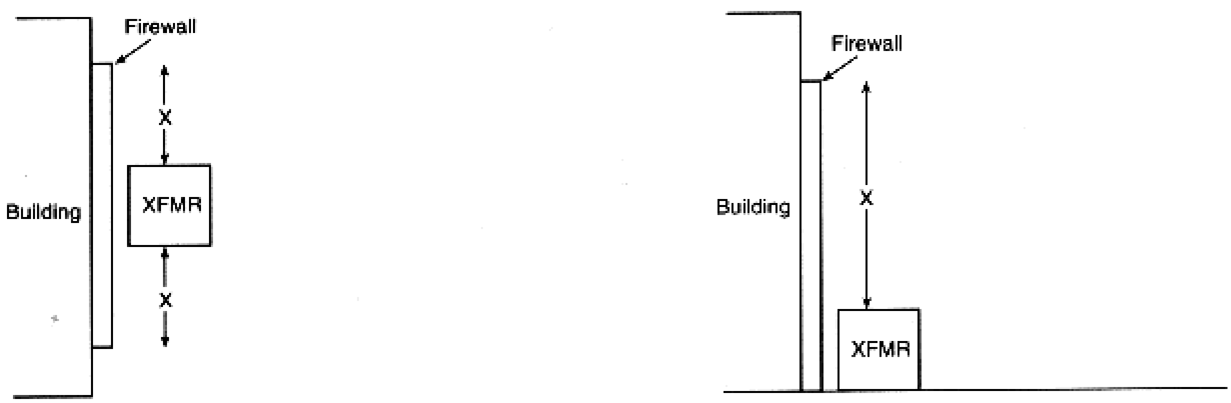
Figure 8-23.1(a) Transformer spacing.



Generic case



Example 1



Example 2

Figure 8-23.1(b) Transformer spacing.

Table 8-23.1 Transformer Spacing Separation Distances

Transformer Oil Capacity	Minimum (Line-of-Sight) Separation without Firewall
Less than 5000 gal (18 925 L)	25 ft (7.6 m)
Over 5000 gal (18 925 L)	50 ft (15.2 m)

8-23.2

Oil-filled main, station service, and start-up transformers shall be protected with automatic water spray systems in accordance with NFPA 15, *Standard for Water Spray Fixed Systems for Fire Protection*, or foam-water spray systems in accordance with NFPA 16, *Standard for the Installation of Deluge Foam-Water Sprinkler and Foam-Water Spray Systems*.

8-23.3

Transformers installed inside fire areas containing safety-related systems or equipment shall be of the dry type or insulated and cooled with noncombustible liquid.

Exception: Transformers filled with combustible fluid that are located indoors shall be enclosed in a transformer vault [see Article 450(c) of NFPA 70].

8-24 Auxiliary Boilers.

8-24.1

Auxiliary boilers, their fuel burning systems, combustion product removal systems, and related control equipment shall be installed and operated in accordance with NFPA 8501, *Standard for Single Burner Boiler Operation*, and NFPA 8502, *Standard for the Prevention of Furnace Explosions/Implosions in Multiple Burner Boilers*.

8-24.2

Oil-fired boilers or boilers using oil ignition within the main plant shall be protected with automatic sprinkler, water spray, or foam-water sprinkler systems covering the boiler area. Sprinkler and water spray systems shall be designed for a minimum density of 0.25 gal/min/ft^2 (10.19 L/min/m^2) over the entire area.

8-25 Offices, Shops, and Storage Areas.

Automatic sprinklers shall be provided for storage rooms, offices, and shops containing combustible materials that present an exposure to surrounding areas that are critical to plant operation, and shall be so located and protected that a fire or the effects of a fire, including smoke, will not adversely affect any safety-related systems or equipment.

8-26 Simulators.

Simulators shall be provided with a fixed automatic suppression system. Simulators and supporting equipment shall be separated from other areas by a fire barrier with a minimum 1-hr rating.

8-27 Technical Support and Emergency Response Centers.

Technical support centers shall be separated from all other areas by fire barriers, or separated from all other buildings by at least 50 ft (15.2 m), and protected by an automatic fixed suppression system as required by the fire hazards analysis.

8-28 Intake Structures.

Intake structures shall be of noncombustible construction and shall be provided with automatic sprinkler protection.

Chapter 9 Fire Protection for the Construction Site

9-1 General.

9-1.1*

Although many of the activities on nuclear power generating plant construction sites are similar to the construction of other large industrial plants, an above-average level of fire protection is justified due to life safety consideration of the large number of on-site personnel, the high value of materials, and the duration of the construction period. Consideration of fire protection shall include safety to life and potential for delays in construction schedules and plant startup, as well as protection of property. An example of a multi-million dollar fire that resulted in significant property damage, construction delays, and other complications is included in the appendix.

9-1.2

Major construction projects in existing plants present many of the hazards associated with new construction, while presenting additional exposures to an existing nuclear power plant facility. The availability of the existing plant fire protection equipment and the reduction of fire exposure by construction activities are particularly important.

9-1.3

For fire protection for plants and areas under construction, see NFPA 241, *Standard for Safeguarding Construction, Alteration, and Demolition Operations*. This chapter addresses concerns not specifically considered in NFPA 241.

9-2 Administration.

9-2.1

The responsibility for fire protection for the entire site during the construction period shall be clearly defined. The administrative responsibilities shall be to develop, implement, and periodically update as necessary the measures outlined in this standard.

9-2.2

The responsibility for fire protection programs among various organizations on-site shall be clearly delineated. The fire protection program to be followed and the owner’s right to administration and enforcement shall be established.

9-2.3

The fire protection program shall include a fire risk evaluation of the construction site and construction activities.

9-2.4

Written procedures shall be established for the new construction site, including major construction projects in existing plants. Such procedures shall be in accordance with Chapter 3.

9-2.5*

Security guard service, including recorded rounds, shall be provided through all areas of construction during times when construction activity is not in progress (*see NFPA 601*, *Standard on Guard Service in Fire Loss Prevention*).

9-2.6

Construction schedules shall be coordinated so that the planned permanent fire protection systems are installed and placed in service as soon as possible.

9-2.7

Construction and installation of fire barriers and fire doors shall be given priority in the construction schedule.

9-3 Site Clearing and Construction Equipment.

9-3.1 Site Clearing.

9-3.1.1 Prior to clearing forest and brush-covered areas, the owner shall ensure that a written fire control plan is prepared and that fire-fighting tools and equipment are made available as required by NFPA 295, *Standard for Wildfire Control*. Contact shall be made with local fire and forest agencies for current data on restrictions and fire potential, and to arrange for necessary permits.

9-3.1.2 All construction vehicles and engine-driven portable equipment shall be equipped with effective spark arresters. Vehicles equipped with catalytic converters shall be prohibited from wooded and heavily vegetated areas.

9-3.1.3 Fire tools and equipment shall be distinctly marked and used for fire emergencies only.

9-3.1.4 Each site utility vehicle shall be equipped with at least one fire-fighting tool, portable fire extinguisher, or backpack pump filled with 4 gal to 5 gal (15 L to 19 L) of water.

9-3.1.5 Cut trees, brush, and other combustible spoil shall be disposed of promptly.

9-3.1.6* Where it is necessary to dispose of combustible waste by on-site burning, designated burning areas shall be established with approval of the owner and shall be in compliance with federal, state, and local regulations and guidelines. The contractor shall coordinate burning with the agencies responsible for monitoring fire danger in the area and shall obtain all appropriate permits prior to the start of work.

9-3.2 Construction Equipment.

Construction equipment shall meet the requirements of NFPA 512, *Standard for Truck Fire Protection*.

9-4 Construction Warehouses, Shops, and Offices.

9-4.1

All structures that are to be retained as part of the completed plant shall be constructed of materials as indicated in Chapter 6 and in accordance with other applicable sections in this standard.

9-4.2*

Construction warehouses, offices, trailers, sheds, and other facilities for the storage of tools and materials shall be located with consideration of their exposure to major plant buildings or other important structures.

9-4.3*

A fire risk evaluation shall be performed.

9-4.4

Warehouses that contain high-value equipment (as defined by the individual responsible for fire prevention and fire protection), or where the loss of or damage to contents would cause a delay in start-up dates of the completed plant, shall be arranged and protected as indicated below. Although some of these structures are considered to be temporary and will be removed upon completion of the plant, the fire and loss potential shall be thoroughly evaluated and protection provided where warranted.

9-4.4.1 Building construction materials shall be noncombustible or limited combustible.

9-4.4.2 Automatic sprinkler systems shall be designed and installed in accordance with NFPA 13, *Standard for the Installation of Sprinkler Systems*. Waterflow alarms shall be provided and located so as to be monitored at a constantly attended location as determined by the individual responsible for fire protection.

9-4.4.3* Air-supported structures shall only be used for the storage of noncombustibles.

9-4.5

Temporary enclosures, including trailers, inside permanent plant buildings shall be prohibited except where permitted by the individual responsible for fire prevention and fire protection. Where the floor area of a combustible enclosure exceeds 100 ft^2 (9.29 m^2) or where the occupancy presents a fire exposure, the enclosure shall be protected with an approved automatic fire suppression system.

9-4.6

Storage of construction materials, equipment, or supplies that are either combustible or in combustible packaging shall be prohibited in main plant buildings unless the following conditions exist:

(a) An approved automatic fire suppression system is in service in the storage area; or

(b) Where loss of the materials or loss to the surrounding plant area would be minimal, as determined by the individual responsible for fire prevention and fire protection.

9-4.7

Construction areas comprised of mobile buildings arranged with the buildings adjoining each other to form one large fire area shall be avoided. If buildings cannot be adequately separated, fire walls shall be installed between units or automatic sprinklers shall be provided throughout the buildings.

9-4.8

Fire alarms shall be connected to a constantly attended central location.

9-4.9

The handling, storage, and dispensing of flammable liquids and gases shall meet the requirements of NFPA 30, *Flammable and Combustible Liquids Code*; NFPA 58, *Standard for the Storage and Handling of Liquefied Petroleum Gases*; and NFPA 395, *Standard for the Storage of Flammable and Combustible Liquids at Farms and Isolated Sites*.

9-4-10

Vehicle repair facilities shall meet the requirements of NFPA 88B, *Standard for Repair Garages*.

9-5 Construction Site Lay-Down Areas.

9-5.1

Fire hydrant systems with an adequate water supply shall be provided in lay-down areas where the need is determined by the individual responsible for fire prevention and fire protection.

9-5.2

Combustible materials shall be separated by a clear space to allow access for manual fire-fighting equipment. Access shall be provided and maintained to all fire-fighting equipment including fire hoses, extinguishers, and hydrants.

9-6 Temporary Construction Materials.

9-6.1*

Noncombustible or fire-retardant scaffolds, formwork, decking, and partitions shall be used both inside and outside of permanent buildings where a fire could cause substantial damage or delay construction schedules.

9-6.2*

The use of listed pressure-impregnated fire-retardant lumber or listed fire-retardant coatings shall be provided.

9-6.3

Tarpaulins (fabrics) and plastic films shall be certified to conform to the weather-resistant and fire-retardant materials described in NFPA 701, *Standard Methods of Fire Tests for Flame-Resistant Textiles and Films*.

9-6.4

Where it is necessary to store new nuclear fuel in areas other than the permanent storage facilities, a written procedure shall be developed to address separation from combustible materials, security, nuclear criticality, packing material, noncombustible or limited-combustible building materials, standpipe, portable fire extinguishers, and hydrant protection.

9-7 Water Supplies, Supply Mains, and Hydrants.

9-7.1* General.

The permanent underground yard system, fire hydrants, and water supply (at least one water source), as indicated in Chapter 6, shall be installed during the early stages of construction. Where provision of all or part of the permanent underground system and water supply is not practical, temporary systems shall be provided. Temporary water supplies shall be hydrostatically tested, flushed, and arranged to maintain a high degree of reliability, including protection from freezing and loss of power.

9-7.2

Hydrants shall be installed, as indicated in Chapter 6, in the vicinity of main plant buildings, important warehouses, office or storage trailer complexes, and important outside structures with combustible construction or combustible concrete formwork (e.g., cooling towers). The underground main shall be arranged to minimize the possibility that any one break will remove from service any fixed water extinguishing system or leave any area without accessible hydrant protection.

9-7.3

A fire protection water supply shall be provided on the construction site and shall be capable of furnishing the largest of the following for a minimum 2-hr duration:

(a) 500 gal/min (1892.5 L/min), or

(b) The in-service fixed water extinguishing system with the highest water demand and 500 gal/min (1892.5 L/min) for hose streams.

9-7.3.1 The highest water demand shall be determined by the hazards present at the stage of construction, which might not correspond with the highest water demand of the completed plant.

9-7.3.2 As fixed water extinguishing systems are completed, they shall be placed in service, even when the available construction phase fire protection water supply is not adequate to meet the designed system demand. The extinguishing system will provide at least some degree of protection, especially where the full hazard is not yet present. However, when the permanent hazard is introduced, the water supply shall be capable of providing the designed system demand. Where using construction water in permanent systems, adequate strainers shall be provided to prevent clogging of the system by foreign objects and dirt.

9-7.3.3 The water supply shall be sufficient to provide adequate pressure for hose connections at the highest elevation.

9-8 Manual Fire-Fighting Equipment.

9-8.1*

Fire-fighting equipment shall be provided in accordance with NFPA 600, *Standard on Industrial Fire Brigades*, and NFPA 241, *Standard for Safeguarding Construction, Alteration, and Demolition Operations*.

9-8.2

Portable fire extinguishers of suitable capacity shall be provided in accordance with NFPA 10, *Standard for Portable Fire Extinguishers*, where:

(a) Flammable liquids are stored or handled,

(b) Combustible materials are stored,

(c) Temporary oil- or gas-fired equipment is used,

(d) A tar or asphalt kettle is used, or

(e) Welding or open flames are in use.

9-8.3

A standpipe system shall be provided in any permanent building that has two-floor equivalent wall heights erected. Additional standpipe hose connections shall be added to each floor level as soon as sufficient landings are available to fight fires from that level. Protection from freezing shall be provided. (*See NFPA 14, Standard for the Installation of Standpipe and Hose Systems*.)

9-8.4

Hoses and nozzles shall be available at strategic locations, such as inside hose cabinets or hose houses or on dedicated fire response vehicles.

9-8.5

If fire hose connections are not compatible with local fire-fighting equipment, adapters shall be made available.

Chapter 10 Referenced Publications

10-1

The following documents or portions thereof are referenced within this standard and shall be considered part of the requirements of this document. The edition indicated for each reference is the current edition as of the date of the NFPA issuance of this document.

10-1.1 NFPA Publications.

National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.

NFPA 10, *Standard for Portable Fire Extinguishers,* 1994 edition.

NFPA 11, *Standard for Low-Expansion Foam*, 1994 edition.

NFPA 11A, *Standard for Medium- and High-Expansion Foam Systems*, 1994 edition.

NFPA 12, *Standard on Carbon Dioxide Extinguishing Systems*, 1993 edition.

NFPA 13, *Standard for the Installation of Sprinkler Systems*, 1994 edition.

NFPA 14, *Standard for the Installation of Standpipe and Hose Systems*, 1993 edition.

NFPA 15, *Standard for Water Spray Fixed Systems for Fire Protection*, 1990 edition.

NFPA 16, *Standard on the Installation of Deluge Foam-Water Sprinkler and Foam-Water Spray Systems*, 1995 edition.

NFPA 16A, *Standard for the Installation of Closed-Head Foam-Water Sprinkler Systems*, 1994 edition.

NFPA 17, *Standard for Dry Chemical Extinguishing Systems*, 1994 edition.

NFPA 20, *Standard for the Installation of Centrifugal Fire Pumps*, 1993 edition.

NFPA 22, *Standard for Water Tanks for Private Fire Protection*, 1993 edition.

NFPA 24, *Standard for the Installation of Private Fire Service Mains and Their Appurtenances*, 1995 edition.

NFPA 30, *Flammable and Combustible Liquids Code*, 1993 edition.

NFPA 31, *Standard for the Installation of Oil-Burning Equipment*, 1992 edition.

NFPA 37, *Standard for the Installation and Use of Stationary Combustion Engines and Gas Turbines*, 1994 edition.

NFPA 50A, *Standard for Gaseous Hydrogen Systems at Consumer Sites*, 1994 edition.

NFPA 50B, *Standard for Liquefied Hydrogen Systems at Consumer Sites*, 1994 edition.

NFPA 51B, *Standard for Fire Prevention in Use of Cutting and Welding Processes*, 1994 edition.

NFPA 54, *National Fuel Gas Code*, 1992 edition.

NFPA 58, *Standard for the Storage and Handling of Liquefied Petroleum Gases*, 1995 edition.

NFPA 70, *National Electrical Code*, 1996 edition.

NFPA 72, *National Fire Alarm Code*, 1993 edition.

NFPA 75, *Standard for the Protection of Electronic Computer/Data Processing Equipment*, 1995 edition.

NFPA 80, *Standard for Fire Doors and Fire Windows*, 1995 edition.

NFPA 88B, *Standard for Repair Garages*, 1995 edition.

NFPA 90A, *Standard for the Installation of Air Conditioning and Ventilating Systems*, 1993 edition.

NFPA *101*, *Life Safety Code*, 1994 edition.

NFPA 211, *Standard for Chimneys, Fireplaces, Vents, and Solid Fuel-Burning Appliances*, 1992 edition.

NFPA 214, *Standard on Water-Cooling Towers*, 1992 edition.

NFPA 220, *Standard on Types of Building Construction*, 1995 edition.

NFPA 232, *Standard for the Protection of Records*, 1995 edition.

NFPA 241, *Standard for Safeguarding Construction, Alteration, and Demolition Operations*, 1993 edition.

NFPA 251, *Standard Methods of Tests of Fire Endurance of Building Construction and Materials*, 1995 edition.

NFPA 252, *Standard Methods of Fire Tests of Door Assemblies*, 1995 edition.

NFPA 253, *Standard Method of Test for Critical Radiant Flux of Floor Covering Systems Using a Radiant Heat Energy Source*, 1990 edition.

NFPA 255, *Standard Method of Test of Surface Burning Characteristics of Building Materials*, 1990 edition.

NFPA 256, *Standard Methods of Fire Tests of Roof Coverings*, 1993 edition.

NFPA 259, *Standard Test Method for Potential Heat of Building Materials*, 1993 edition.

NFPA 295, *Standard for Wildfire Control*, 1991 edition.

NFPA 395, *Standard for the Storage of Flammable and Combustible Liquids at Farms and Isolated Sites*, 1993 edition.

NFPA 512, *Standard for Truck Fire Protection*, 1994 edition.

NFPA 600, *Standard on Industrial Fire Brigades*, 1992 edition.

NFPA 601, *Standard on Guard Service in Fire Loss Prevention*, 1992 edition.

NFPA 701, *Standard Methods of Fire Tests for Flame-Resistant Textiles and Films*, 1989 edition.

NFPA 780, *Standard for the Installation of Lightning Protection Systems*, 1995 edition.

NFPA 1500, *Standard on Fire Department Occupational Safety and Health Program*, 1992 edition.

NFPA 2001, *Standard on Clean Agent Fire Extinguishing Systems*, 1994 edition.

NFPA 8501, *Standard for Single Burner Boiler Operation*, 1992 edition.

NFPA 8502, *Standard for the Prevention of Furnace Explosions/Implosions in Multiple Burner Boilers*, 1995 edition.

10-1.2 Other Publications.

10-1.2.1 ANSI Publications. American National Standards Institute, 130 Broadway, New York, NY 10018.

ANSI B31.1, *Code for Power Piping*, 1992 edition.

ANSI C2, *National Electrical Safety Code*, 1993 edition.

10-1.2.2 ASME Publications. American Society of Mechanical Engineers, 345 East 47th Street, New York, NY 10017.

ASME *Boiler and Pressure Vessel Code*, Section III, 1992 edition.

ASME NQA-1, *Quality Assurance Program Requirements for Nuclear Facilities*, 1994 edition.

10-1.2.3 ASTM Publications. American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103.

ASTM D 92, *Standard Test Method for Flash and Fire Points by Cleveland Open Cup*, 1990 edition.

ASTM E 84, *Standard Test Method for Surface Burning Characteristics of Building Materials*, 1994 edition.

ASTM E 119, *Standard Test Methods for Fire Tests of Building Construction and Materials*, 1988 edition.

ASTM E 136, *Standard Test Method for Behavior of Materials in a Vertical Tube Furnace at 750°*, 1994 edition.

ASTM E 814, *Fire Tests of Through-Penetration Fire Stops*, 1994 edition.

10-1.2.4 IEEE Publication. Institute of Electrical and Electronics Engineers, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331.

IEEE 383-1974 (R-1992) *Standard for Type Test of Class IE Electric Cables*, Field Splices and Connections for Nuclear Power Generating Stations.

10-1.2.5 UL Publications. Underwriters Laboratories Inc., 333 Pfingsten Road, Northbrook, IL 60062.

UL 586, *Standard for Test Performance of High-Efficiency Particulate Air Filter Units*, 1990 edition.

UL 1479, *Standard for Safety Fire Tests of Through-Penetration Firestops*, 1994 edition.

10-1.2.6 U.S. Government Publications. U.S. Government Printing Office, Washington, DC 20402.

NRC Generic Letter 86-10, Supplement 1.

Title 10, *Code of Federal Regulations*, Part 100.

Appendix A Explanatory Material

This Appendix is not a part of the requirements of this NFPA document but is included for information purposes only.

A-1-1

This standard does not address water-moderated or -cooled nuclear reactors used for training, testing, experimental purposes, or the production of special nuclear materials as defined in the Atomic Energy Act of 1954, as amended. Refer to NFPA 802, *Recommended Fire Protection Practice for Nuclear Research and Production Reactors*.

This standard does not address light water nuclear power plants with construction permits issued prior to January 1, 1979. Refer to NFPA 803, *Standard for Fire Protection for Light Water Nuclear Power Plants*.

A-1-4 Advanced Light Water Reactors.

Principal examples of evolutionary plant design include the General Electric advanced boiling water reactor (ABWR), the Westinghouse advanced pressurized water reactor (APWR), and the Asea Brown Boveri-Combustion Engineering System 80+ reactor. Principal examples of revolutionary plant design include the General Electric simplified boiling water reactor (SBWR) and the Westinghouse AP-600.

A-1-4 Approved.

The National Fire Protection Association does not approve, inspect, or certify any installations, procedures, equipment, or materials; nor does it approve or evaluate testing laboratories. In determining the acceptability of installations, procedures, equipment, or materials, the authority having jurisdiction may base acceptance on compliance with NFPA or other appropriate standards. In the absence of such standards, said authority may require evidence of proper installation, procedure, or use. The authority having jurisdiction may also refer to the listings or labeling practices of an organization concerned with product evaluations that is in a position to determine compliance with appropriate standards for the current production of listed items.

A-1-4 Authority Having Jurisdiction.

The phrase “authority having jurisdiction” is used in NFPA documents in a broad manner, since jurisdictions and approval agencies vary, as do their responsibilities. Where public safety is primary, the authority having jurisdiction may be a federal, state, local, or other regional department or individual such as a fire chief; fire marshal; chief of a fire prevention bureau, labor department, or health department; building official; electrical inspector; or others having statutory authority. For insurance purposes, an insurance inspection department, rating bureau, or other insurance company representative may be the authority having jurisdiction. In many circumstances, the property owner or his or her designated agent assumes the role of the authority having jurisdiction; at government installations, the commanding officer or departmental official may be the authority having jurisdiction.

A-1-4 Fire Area.

Where an exterior wall forms a part of the fire area boundary, it should be evaluated to determine if it is required to be fire rated based on potential exposures.

A-1-4 Fire Area Subdivision.

The phrase “fire zone” typically has been used to address both portions of fire areas and divisions of suppression and detection systems. To provide clarity, this standard has created two separate phrases: “fire area subdivision” and “fire zone.” It should be noted that there might be cases in which these two terms could be describing the same location. An example might include a pump bay with concrete barriers (but without all penetrations sealed), which is protected by its own sprinkler system, and detection that annunciates an alarm specifically for the pump bay. It is acceptable to describe such a location as both a fire area subdivision and a fire zone.

A-1-4 Fire Brigade.

Fire brigades can be staffed by shift personnel with collateral responsibilities or by personnel whose primary responsibility is fire-fighting activities (a plant fire department).

A-1-4 Fire-Rated Cables.

At this time, there is no nationally recognized standard to test and qualify fire-rated cables. The cables should be tested in accordance with the time-temperature curve in NFPA 251, *Standard Methods of Tests of Fire Endurance of Building Construction and Materials*. The cables should remain functional for the required rating period.

A-1-4 Listed.

The means for identifying listed equipment may vary for each organization concerned with product evaluation, some of which do not recognize equipment as listed unless it is also labeled. The authority having jurisdiction should utilize the system employed by the listing organization to identify a listed product.

A-2-4

Where any of the analyses in Section 2-4 have been performed elsewhere, they need only be referenced as part of the fire hazards analysis.

A-2-4(b) A subdivision inventory or table should be prepared and maintained for each fire area. All in situ combustible and flammable materials and their configurations should be identified. Where the in situ combustibles present an exposure to nuclear-safety-related systems and components, they should be uniquely identified. Transient combustibles that are expected to be in place during normal plant operating modes also should be identified. The combustible storage areas should not present a threat to nuclear-safety-related systems and components.

A-2-6.1(b) Inspections, tests, administrative controls, fire drills, and training that govern the fire protection program should be prescribed by documented instructions, procedures, or drawings and should be accomplished in accordance with these documents.

A-2-6.1(c) Measures should be established to ensure that purchased material, equipment, and services conform to the procurement documents.

A-2-6.1(d) A program for independent inspection of activities affecting fire protection should be established and executed by or for the organization performing the activity to verify conformance with documented installation drawings and test procedures for accomplishing the activities.

A-2-6.1(e) A test program should be established and implemented to ensure that testing is performed and verified by inspection and audit to demonstrate conformance with design and system readiness requirements. The tests should be performed in accordance with written test procedures; test results should be properly evaluated and acted on.

A-2-6.1(f) Measures should be established to provide for the identification of items that have satisfactorily passed necessary tests and inspections.

A-2-6.1(g) Measures should be established to control items that do not conform to specified requirements to prevent inadvertent use or installation.

A-2-6.1(h) Measures should be established to ensure that conditions adverse to fire protection, such as failures, malfunctions, deficiencies, deviations, defective components, uncontrolled combustible material, and nonconformances, are promptly identified, reported, and corrected.

A-2-6.1(i) Records should be prepared and maintained to furnish evidence that the criteria enumerated in 2-6.1 are being met for activities affecting the fire protection program.

A-2-6.1(j) Audits should be conducted and documented to verify compliance with the fire protection program, including design and procurement documents, instructions, procedures and drawings, and inspection and test activities.

A-3-1.2

Plant outages can create conditions not specifically addressed by the administrative controls and fire prevention practices established in Chapter 3. Fire protection personnel should participate in outage planning to determine if unusual challenges will be presented to the fire protection program. Plans should be developed to address conditions not already covered by existing procedures. In addition, extra vigilance to adherence to administrative controls is important during outages. The amount of work activities occurring during outages increases the risk of fire during this time.

A-3-3.1

Combustible materials in both large and small concentrations will be present in nuclear power plants, as in most other industrial plants, and it should be assumed that outbreaks of fire occur for a variety of reasons.

A-3-3.1.1 Typical examples of flammable and combustible materials found in a nuclear power plant are:

(a) Conventional fuels for emergency power units, auxiliary boilers, etc.;

(b) Lubricants and hydraulic oils;

(c) Insulating materials (thermal and electric);

(d) Building materials (including PVC and other plastics);

(e) Filtering materials (e.g., oil-bath filters, charcoal, etc.);

(f) Cleansing materials;

(g) Paints and solvents;

(h) Packaging materials (e.g., bitumen, etc.);

(i) Neutron shields (if organic materials); or

(j) Clothing.

Typical examples of flammable gases found in a nuclear power plant are:

(a) Hydrogen for generator cooling, for coolant conditioning of pressurized water and gas-cooled reactors, and from battery charging;

(b) Propane or other fuel gases;

(c) Hydrogen (H_2) by radiolysis in the core and addition of H_2 for improved recombination;

(d) Gas for cutting and welding; and

(e) Oxygen (O_2) (while not a flammable gas, it is an oxidizer and requires similar controls).

Typical examples of radioactive substances external to the reactor are:

(a) Sealed radioactive materials, such as irradiated or plutonium containing fuel elements, or both, irradiated control rods, neutron sources, etc.;

(b) Unsealed radioactive material, such as ion exchanger fillings and filter cartridges that have become loaded with radioactive substances, rad waste materials, etc.; and

(c) Dry low-level radioactive waste.

A-3-3.1.2 Typical examples are:

(a) Replacement of lubricating or hydraulic oils,

(b) Repainting equipment or structures,

(c) Replacement of combustible filter materials,

(d) Scaffolding or dunnage necessary to maintain or replace equipment, or

(e) Spare equipment in shipping crates or boxes awaiting installation.

A-3-3.3.1 The control of temporary fire loads in the plant is essential to provide defense in depth protection. This includes controlling the use of temporary buildings including trailers, shacks, or shanties within the confines of the plant; the use of noncombustible scaffolds, formwork, decking, and partitions both inside and outside permanent buildings; and the use of noncombustible tarpaulins.

All combustible packing containers should be removed from the area immediately following unpacking. No such combustible material should be left unattended during lunch breaks, shift changes, or other similar periods. Loose combustible packing material such as wood or paper excelsior, polyethylene sheeting, or expanded polystyrene should be placed in metal containers with tight-fitting, self-closing metal covers.

A-3-3.3.4 Particular attention should be given to the control of halogenated plastics.

A-3-3.4.4(a) Oil pipes should be located below steam lines.

A-3-4.1.3 If welding operations have been conducted during the previous work period, the oncoming watchperson should be alerted to check the location where welding was done as part of his or her regular rounds. Where watch service is not provided, use of gas-operated welding or cutting equipment should be discontinued a minimum of 1 hr before quitting time. Where practical, work should be moved to a safe location to be welded. Torches should not be used to cut holes in walls, floors, ceilings, or roofs containing combustible insulation, framing, sheathing, or finished material.

A-3-5.1.1 Grouped noncombustible buildings, trailers, and sheds with separation between individual units less than that specified by NFPA 80A, *Recommended Practice for Protection of Buildings from Exterior Fire Exposures*, or grouped combustible or limited-combustible buildings, trailers, or sheds with separation between individual units less than 30 ft (9.1 m) should be considered as a single building.

A-3-6.1

The impairment procedure should include the following:

(a) Identification of equipment that is not available for service;

(b) List of those to be notified of impairments (e.g., operations personnel, plant fire brigade personnel, the insurance company, etc.);

(c) Compensatory measures (e.g., increased surveillance on other systems, fire watch patrols);

(d) Target durations for impaired equipment (i.e., escalation of management attention to impaired equipment to ensure prompt corrective action); and

(e) Consideration of plant status (i.e., compensatory measures can be relaxed for impairment of certain systems during outage conditions).

This list can be modified as needed to include any site-specific actions or regulatory commitments.

While impairments to fire protection systems protecting both safe shutdown areas and balance of plant areas are to be included in the procedure, there might be differences in various aspects of the programs (e.g., compensatory measures might be more stringent for impaired systems protecting safe shutdown equipment).

A-3-6.2

When impairments are planned, the necessary equipment and personnel for the repair or service should be staged in advance. When the impairment is unplanned, those responsible for fire protection should ensure that the repair is given the appropriate priority and should bring delays in repair to management’s attention.

A-3-6.3

Post-maintenance testing of a system prior to return to service after an impairment is critical to ensure proper functioning. This is not necessary in cases where there was no actual repair or modification work performed on the impaired system. The appropriate level of testing should be established by those most knowledgeable of the impaired system. Section 3-7 and the appropriate NFPA standard addressing the type of system impaired should be used when considering the type of post-maintenance testing that is necessary.

A-3-7.2

Normally NFPA standards are used to determine the frequency and type of inspection, testing, and maintenance performed on systems installed for fire protection. Table A-3-7.2 is provided as a reference for this purpose. However, there are considerations and configurations at nuclear power plants that might make it difficult or impracticable to follow the exact requirements of the NFPA standard. In these situations, those responsible for fire protection at the plant need to establish the appropriate inspection, testing, and maintenance frequency and type. For example, fire protection systems installed in containment or high radiation areas might only be accessible during outages. Water disposal considerations might limit certain sprinkler system tests within radioactive controlled areas.

Table A-3-7.2 Reference Guide for Fire Equipment Inspection, Testing, and Maintenance

Item	NFPA Document
Supervisory and Fire Alarm Circuits	72
Fire Detectors	72
Manual Fire Alarms	72
Sprinkler Water Flow Alarms	25, 72
Sprinkler and Water Spray Systems	15, 25
Foam Systems	11A, 11C, 16
Halogenated Agent, Chemical, and CO_2 Systems	12, 12A, 17
Fire Pumps and Booster Pumps	20
Water Tanks and Alarms	22, 25, 72
PIV's and OS&Y Valves	25, 72
Fire Hydrants and Associated Valves	24, 25
Fire Hose and Standpipes	14, 1962
Portable Fire Extinguishers and Hose Nozzles	10, 1962
Fire Brigade Equipment	1972
Fire Doors	80
Smoke Vents	204M

Emergency Lighting	70
Radio Communication Equipment	1221
Audible and Visual Signals	72

A-3-7.4

Certain plant systems and equipment, including the turbine generator, transformers, large pumps, etc., will have a large impact on the level of fire risk at a plant. While typically there are programs in place to perform inspections, tests, and maintenance of these systems, those responsible for fire protection should ensure that this testing is adequate to minimize the fire risk.

A-4-1.2

Water drainage methods should be reviewed and included in that area's prefire plans.

A-4-1.4

Consideration should be given to providing prefire plans to public fire departments that might respond to the site to assist them in the development of their own prefire plans.

A-4-2

The focus of the plant fire brigade is to respond to fires that could impair the ability to safely shut down the plant. Response by the fire brigade to fires and alarms on the owner-controlled property but outside the power block is acceptable. Considerations should be given to such factors as:

(a) Proximity and response capability of local fire department;

(b) Monetary value of other on-site facilities;

(c) Potential for off-site radioactive material release (low level radioactive waste facilities, for example); and

(d) Potential for impact on plant operations due to fire loss (low lead time items in warehouse, for example).

Prefire plans should detail radiologically hazardous areas and radiation protection barriers. Methods of smoke and heat removal should be identified for all fire areas in the prefire plans. This may include the use of dedicated smoke and heat removal systems or the use of the structure's HVAC system if it can operate in the 100 percent exhaust mode.

A-4-5.2.3 Training of the plant fire brigade should be coordinated with the local fire department so that responsibilities and duties are delineated in advance. This coordination should be part of the training course and should be included in the training of the local fire department staff.

Local fire departments should be provided training in operational precautions when fighting fires on nuclear power plant sites and should be made aware of the need for radiological protection of personnel and the special hazards associated with a nuclear power plant site.

A-4-5.3.1 Duties of the person in this position should include overseeing the issuance of security badges, film badges, and dosimetry to the responding public fire-fighting forces, and ensuring that the responding off-site fire department(s) are escorted to the designated point of entry to the plant.

A-4-9

Methods of manual smoke and heat removal should consider the use of portable ventilation equipment as well as the natural migration of smoke and heat due to either natural or mechanical air movement within the building or buildings.

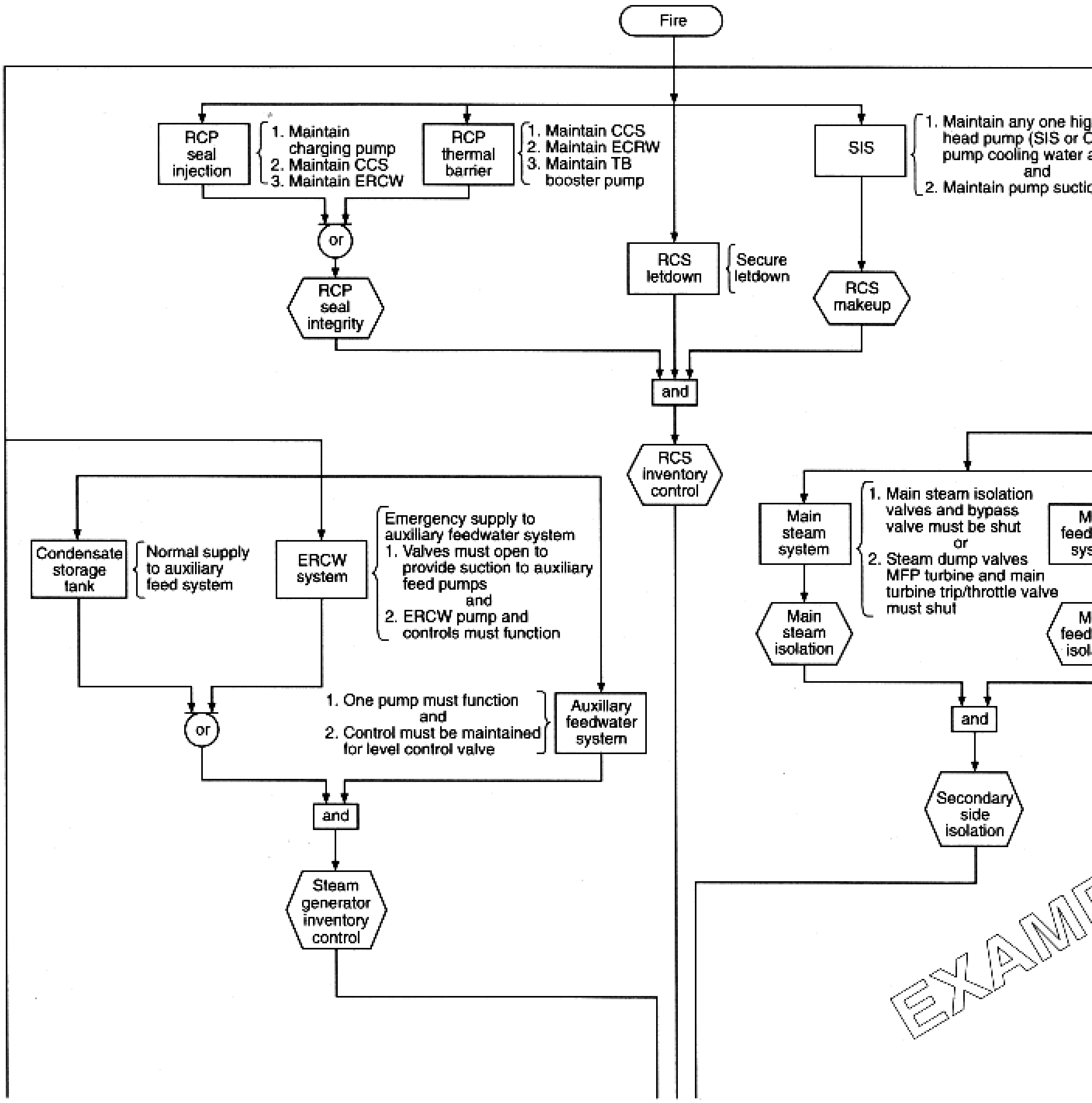


Figure A-5-2.2.2 Typical shutdown logic diagram — fire (Source: ANS-59.4-1979) (continued on next page).

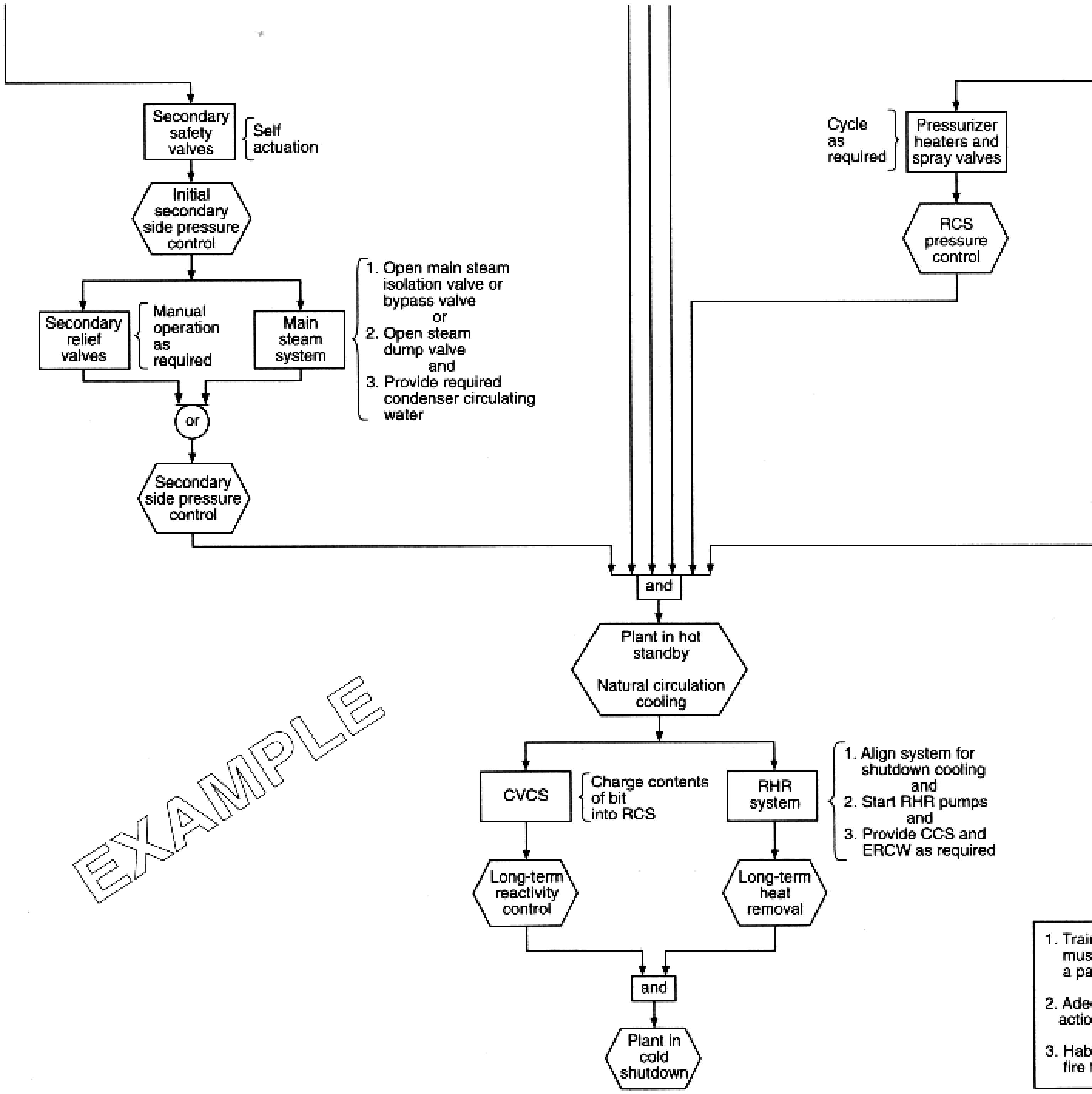


Figure A-5-2.2.2 Typical shutdown logic diagram — fire (Source: ANS-59.4-1979) (continued).

A-5-2.3.1 Currently the fire-induced vulnerability evaluation (FIVE) methodology and fire probabilistic risk assessment (PRA) are available.

A-5-2.3.2 The value of 1×10^{-6} per reactor year is based on NRC Generic Letter 88-20, Supplement 4.

A-5-3.1.2 These components include nuclear-safety-related and safe shutdown components. Components outside the fire area that are electrically or mechanically dependent upon fire-damaged components within the fire area should be considered within the analysis.

A-5-3.1.3 This can be accomplished by the use of rated barriers, fire-rated cables, an electrical raceway fire barrier system, physical separation, or a combination of these methods.

A-5-3.1.8(c) Due to their design, revolutionary plants will achieve and maintain cold shutdown conditions only after an extended period of time.

A-5-3.1.12 For three-phase ac circuits, the probability of getting a hot short on all three phases in the proper sequence to cause spurious operation of a motor is considered sufficiently low and additional evaluation, except for the case involving high-to-low pressure interface, is not necessary.

A-5-3.1.14 These devices protect the function of the safety circuit in the event of fire damage to the associated circuits of concern.

A-5-3.1.15 Associated circuits of concern not necessary to achieve safe shutdown might be found to share a common enclosure. Fire-initiated electrical fault currents could be generated on unprotected nonsafe shutdown cables. If a fault current is of sufficient magnitude, a secondary fire might be initiated in the common enclosure shared with shutdown cable.

A-5-3.2

Review of seismic-induced fire experience data performed by the Electric Power Research Institute (EPRI), the Seismic Qualification Utilities Group (SQUG), and others suggests there is minimal threat of seismic-induced fires in nuclear power plants. Review of more than 100 power plant and industrial sites in 18 strong ground-motion earthquakes revealed only 4 instances of seismic-induced fires. The causes of these fires were attributed to arcing of high voltage equipment, chemical laboratory fire, and oil-soaked insulation on piping. This low incidence of approximately 4 percent represents installations primarily in high seismic hazard regions, designed to commercial and industrial codes and standards.

A-5-3.2.2 Guidance is provided in NRC Generic Letter 88-20, Supplement 4, “Sandia Risk Scoping Items.”

A-5-5.2.2 Repairs such as lifting leads or pulling of fuses should not be necessary to achieve shutdown of the reactor.

A-5-5.3.1.1 Stairwells in such routes should be enclosed in masonry or concrete towers with a minimum fire rating of 2 hr and should be provided with self-closing, Class B fire doors. The stairwells should be designed with smoke-control features.

A-5-5.3.2.1 Operators should not be required to perform any unsafe physical actions.

A-5-5.3.2.2 Operators should not be required to perform any physical operations that are outside of their normal physical abilities.

A-6-2.1

Conformance with the NFPA *101*, *Life Safety Code*, satisfies OSHA requirements for means of egress.

A-6-2.2

The operation and maintenance of an ALWR plant involves unique operations and materials in process.

A-6-3.2

Many plastic materials, including flame- and fire-retardant materials, will burn with an intensity and energy production in the range similar to that of ordinary hydrocarbons. When burning, they produce heavy smoke that obscures visibility and can plug air filters, especially charcoal and HEPA filters. The halogenated plastics also release free chloride and hydrogen chloride when burning, which are toxic to humans and corrosive to equipment.

A-6-3.7.2 This will minimize the possibility of wall penetration in the event of a container failure.

A-6-4

Suitable design of the ventilation system can limit the consequences of a fire by preventing the spread of the products of combustion to other fire areas. The design of the ventilation system should provide a means to ventilate, exhaust, or isolate the fire area as necessary, and consideration should be given to the consequences of failure of the ventilation system due to fire causing loss of control for ventilating, exhausting, or isolating a given fire area. The capability to ventilate, exhaust, or isolate is particularly important to ensure the habitability of rooms and spaces that should be attended in the fire emergency. In the design, provisions should be made for personnel access to and escape routes from each fire area.

A-6-4.1

For further information, see NFPA 92A, *Recommended Practice for Smoke-Control Systems*, and NFPA 204M, *Guide for Smoke and Heat Venting*.

A-6-4.2

The need for automatic dampers or shutdown can be avoided by installing separate ventilation systems for each fire area, or by installing fire-resistive ducting enclosures. Additional filter protection might be necessary.

A-6-5.1

Refer to Appendix A of NFPA 15, *Standard for Water Spray Fixed Systems for Fire Protection*, for additional information on drainage.

A-6-5.3(d) Brazed, soldered, and clamp-type fittings as well as nonferrous and plastic piping are susceptible to melting under fire conditions. Ferrous piping, where internal liquids are confined, is subject to bursting under fire conditions.

A-6-9

See NFPA 80A, *Recommended Practice for Protection of Buildings from Exterior Fire Exposures*.

A-6-11.2

Multi-channel portable radios are used for communications at nuclear power plants.

Subsections 6-11.2 and 6-11.3 do not prohibit sharing of radio channels by various station groups. The use and assignment of channels should ensure that the fire brigade, operations, and security all can use the radios to carry out their functions during a fire emergency.

A-6-11.5

In unique or unusual circumstances where equipment cannot be designed to prevent radio frequency interference, the authority having jurisdiction can permit the area around the sensitive equipment where portable radios cannot be used to be identified and marked so that fire fighters can readily recognize the condition. Training in this recognition also should be provided.

A-7-1.1

Automatic sprinkler protection provides the best means for controlling fires and should be provided. Special hazards might necessitate additional fixed protection systems as indicated by the fire hazards analysis.

A-7-1.2

Mitigating severe accident events that can result in fuel-clad damage is a top priority. Since fires and other severe plant accidents are not assumed to occur simultaneously, fire protection systems do not need to be designed to handle both demands simultaneously.

A-7-2.1

The water supply for the permanent fire protection water system should be based on providing a 2-hr water supply for both items (a) and (b) as follows:

(a) Either of items (1) or (2) below, whichever is larger:

1. The largest fixed fire suppression system demand; or

2. Any fixed fire suppression system demand that could be reasonably expected to operate simultaneously during a single event (e.g., turbine underfloor protection in conjunction with other fire protection systems in the turbine area).

(b) The hose stream demand of not less than 500 gal/min (1892.5 L/min).

A-7-2.2

Due to the 100 percent redundancy feature of two tanks, refill times in excess of 8 hr are acceptable.

A-7-2.3

The intent of this section is to provide a water supply that will not be susceptible to biofouling, scaling, microbiologically induced corrosion (MIC), or sedimentation.

A-7-2.4.2 For maximum reliability, three fire pumps should be provided so that two pumps meet the maximum demand plus hose streams. Two fire pumps could be an acceptable alternate, provided either of the fire pumps can supply the maximum demand plus hose streams within 120 percent of its rated capacity.

A-7-4.9

Guidance on safe distances for water application to live electrical equipment can be found in the *NFPA Fire Protection Handbook*.

A-7-4.10.1 The water supply for this condition is permitted to be obtained by manual operator actuation of valves in a connection to the hose standpipe header from a normal seismic Category 1 water system such as the essential service water system.

A-7-7.2

This is also referred to as a Class A system.

A-7-7.4

Visual signaling appliances can be used to supplement audible appliances in the protected area.

A-8-1

Examples of such hazards include lubricating oil or hydraulic fluid systems for the primary coolant pumps, cable tray arrangements and cable penetration, and charcoal filters. Because of the general inaccessibility of the primary containment during normal plant operation, protection should be provided by automatic fixed suppression systems. The effects of postulated fires within the primary containment should be evaluated to ensure that the integrity of the primary coolant system and the containment are not jeopardized assuming no manual action is taken to fight the fire.

A-8-2.2.1 Refueling and maintenance operations in containment might introduce additional hazards such as containment control materials, decontamination supplies, wood planking, temporary wiring, welding, and flame cutting (with portable compressed-gas fuel supply). Possible fires would not necessarily be in the vicinity of the installed fire detector and suppression systems.

A-8-4.1.3(d) It might be beneficial to provide continuous line-type heat detectors in the cable trays where the cable trays are stacked more than three cable trays high or over 18 in. (457.2 mm) wide, in addition to the area smoke detection systems.

A-8-4.2.1 It might be beneficial to provide continuous line-type heat detectors in the cable trays where the cable trays are stacked more than three cable trays high or over 18 in. (457.2 mm) wide, in addition to the area smoke detection systems.

A-8-6.1

Switchgear should be raised off the floor.

A-8-7.1

For further information refer to IEEE 484, *Recommended Practice for Installation Design and Installation of Large Lead Batteries for Generating Stations and Substations*.

A-8-8.1

Smoke and heat vents or sprinkler protection at the roof level is necessary to protect the turbine building structure.

A-8-8.2.1 To avoid water application to hot parts or other water-sensitive areas and to provide adequate coverage, designs that incorporate items such as fusible element operated spray nozzles might be necessary.

A-8-8.3

Additional information concerning turbine generator fire protection can be found in EPRI Research Report 1843-2, “Turbine Generator Fire Protection by Sprinkler System,” July 1985.

A-8-8.8.1.7 The preferable arrangement from a fire risk standpoint is to keep the bulk storage isolated from the generator by shutting the block valve outdoors. Makeup should be done manually as necessary, logging hydrogen usage to track consumption. This procedure allows for ongoing indication of what is being used, and it prevents the system from feeding hydrogen during a fire emergency if there is a failure at one of the generator shaft seals.

A-8-8.10

It is desirable to provide for remote operation, preferably from the control room, of the condenser vacuum break valve and the lubricating pumps. Breaking the condenser vacuum markedly reduces the rundown time for the turbine generator and thus limits oil discharge in the event of a leak.

A-8-8.10.4 On some turbine generators employing the guard pipe principle, the guard piping arrangement terminates under the machine housing where feed and return piping run to pairs of bearings. Such locations are vulnerable to breakage with attendant release of oil in the event of excessive vibration and should be protected.

A-9-1.1

A 1971 fire occurred in the primary auxiliary building of a U.S. nuclear power plant under construction. The fire originated in a combustible construction shed. At the time of the fire, nuclear fuel had been loaded and the reactor vessel head was removed. The fire spread to the cable system and caused considerable damage to three motor control centers, which provided power to many of the engineered safety features. The two-hour fire was fought by the off-site fire departments from three local communities. Arson was suspected to have been the cause of this $2,100,000 fire, which delayed the startup of the plant.

A-9-2.5

The first round should be conducted one-half hour after the suspension of work for the day. Thereafter, rounds should be made every hour. Where partial construction activities occur on second and third shifts, the guard service rounds can be modified to include only unattended or sparsely attended areas. In areas where automatic fire detection or extinguishing systems are in service, with alarm annunciation at a constantly attended location, or in areas of limited combustible loading, rounds can be omitted after the first round.

A-9-3.1.6 Local conditions might require the establishment of fire breaks by clearing or use of selective herbicides in areas adjacent to property lines and access roads.

A-9-4.2

For guidance in separation and protection see NFPA 80A, *Recommended Practice for Protection of Buildings from Exterior Fire Exposures*.

A-9-4.3

Large central office facilities might be of substantial value and contain high-value computer equipment, irreplaceable construction records, or other valuable contents, the loss of which can result in significant construction delays.

This evaluation might indicate a need for automatic sprinkler systems or other protection or the desirability of subdividing the complex to limit values exposed by one fire.

A-9-4.4.3 Air-supported structures sometimes are used to provide temporary warehousing space.

Although the fabric envelope might be a fire-retardant material, the combustibility of contents and the values should be considered, as with any other type of warehouse. Because it is impractical to provide automatic sprinkler protection for them, air-supported structures should be used only for noncombustible storage. An additional consideration is that relatively minor fire damage to the fabric envelope might leave the contents exposed to the elements.

A-9-6.1

The use of noncombustible or fire-retardant concrete formwork is especially important for large structures (e.g., reactor building and turbine generator pedestal) where large quantities of forms are used.

A-9-6.2

Pressure-impregnated fire-retardant lumber should be used in accordance with its listing and the manufacturer's instructions. Where exposed to the weather or moisture (e.g., concrete forms), the fire retardant used should be suitable for this exposure. Fire-retardant coatings are not acceptable on walking surfaces or surfaces subject to mechanical damage.

A-9-7.1

The necessary reliability of construction water supplies, including redundant pumps, arrangement of power supplies, and use of combination service water and construction fire protection water, should be determined by the individual responsible for fire protection.

A-9-8.1

Mobile fire-fighting equipment can be utilized to provide necessary fire-fighting equipment.

Appendix B Referenced Publications

B-1

The following documents or portions thereof are referenced within this standard for informational purposes only and thus are not considered part of the requirements of this document. The edition indicated for each reference is the current edition as of the date of the NFPA issuance of this document.

B-1.1 NFPA Publications.

National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.

NFPA *Fire Protection Handbook*, 17th edition.

NFPA 10, *Standard for Portable Fire Extinguishers*, 1994 edition.

NFPA 11A, *Standard for Medium- and High-Expansion Foam Systems*, 1994 edition.

NFPA 11C, *Standard for Mobile Foam Apparatus*, 1995 edition.

NFPA 12, *Standard on Carbon Dioxide Extinguishing Systems*, 1993 edition.

NFPA 12A, *Standard on Halon 1301 Fire Extinguishing Systems*, 1992 edition.

NFPA 14, *Standard for the Installation of Standpipe and Hose Systems*, 1993 edition.

NFPA 15, *Standard for Water Spray Fixed Systems for Fire Protection*, 1990 edition.

NFPA 16, *Standard on the Installation of Deluge Foam-Water Sprinkler and Foam-Water Spray Systems*, 1995 edition.

NFPA 17, *Standard for Dry Chemical Extinguishing Systems*, 1994 edition.

NFPA 20, *Standard for the Installation of Centrifugal Fire Pumps*, 1993 edition.

NFPA 22, *Standard for Water Tanks for Private Fire Protection*, 1993 edition.

NFPA 24, *Standard for the Installation of Private Fire Service Mains and Their Appurtenances*, 1995 edition.

NFPA 25, *Standard for the Inspection, Testing, and Maintenance of Water-Based Fire Protection Systems*, 1995 edition.

NFPA 30, *Flammable and Combustible Liquids Code*, 1993 edition.

NFPA 50A, *Standard for Gaseous Hydrogen Systems at Consumer Sites*, 1994 edition.

NFPA 50B, *Standard for Liquefied Hydrogen Systems at Consumer Sites*, 1994 edition.

NFPA 51B, *Standard for Fire Prevention in Use of Cutting and Welding Processes*, 1994 edition.

NFPA 70, *National Electrical Code*, 1996 edition.

NFPA 72, *National Fire Alarm Code*, 1993 edition.

NFPA 80, *Standard for Fire Doors and Fire Windows*, 1995 edition.

NFPA 80A, *Recommended Practice for Protection of Buildings from Exterior Fire Exposures*, 1993 edition.

NFPA 90A, *Standard for the Installation of Air Conditioning and Ventilating Systems*, 1993 edition.

NFPA 92A, *Recommended Practice for Smoke-Control Systems*, 1993 edition.

NFPA *101*, *Life Safety Code*, 1994 edition.

NFPA 204M, *Guide for Smoke and Heat Venting*, 1991 edition.

NFPA 220, *Standard on Types of Building Construction*, 1995 edition.

NFPA 241, *Standard for Safeguarding Construction, Alteration, and Demolition Operations*, 1993 edition.

NFPA 251, *Standard Methods of Tests of Fire Endurance of Building Construction and Materials*, 1995 edition.

NFPA 252, *Standard Methods of Fire Tests of Door Assemblies*, 1995 edition.

NFPA 601, *Standard on Guard Service in Fire Loss Prevention*, 1992 edition.

NFPA 802, *Recommended Fire Protection Practice for Nuclear Research and Production Reactors*, 1993 edition.

NFPA 803, *Standard for Fire Protection for Light Water Nuclear Power Plants*, 1993 edition.

NFPA 1221, *Standard for the Installation, Maintenance, and Use of Public Fire Service Communication Systems*, 1994 edition.

NFPA 1962, *Standard for the Care, Use, and Service Testing of Fire Hose Including Couplings and Nozzles*, 1993 edition.

NFPA 1972, *Standard on Helmets for Structural Fire Fighting*, 1992 edition.

B-1.2 Other Publications.

B-1.2.1 ANS Publication. American Nuclear Society, 555 N. Kensington Avenue, LaGrange Park, IL 60525.

ANS 59.4, *Generic Requirements for Light Water Nuclear Power Plant Fire Protection,* 1979 edition.

B-1.2.2 ANSI Publication. American National Standards Institute, 130 Broadway, New York, NY 10018.

ANSI C2, *National Electrical Safety Code,* 1993 edition.

B-1.2.3 EPRI Publication. Electric Power Research Institute, 3412 Hillview Avenue, Palo Alto, CA 94303.

EPRI Research Report 1843-2, "Turbine Generator Fire Protection by Sprinkler System," July 1985.

B-1.2.4 IEEE Publication. Institute of Electrical and Electronics Engineers, 345 East 47th Street, New York, NY 10017.

IEEE 484, *Recommended Practice for Installation Design and Installation of Large Lead Batteries for Generating Stations and Substations*, 1987 edition.

B-1.2.5 U.S. Government Publications. U.S. Government Printing Office, Washington, DC 20402.

Title 10, *Code of Federal Regulations,* Part 100, "Reactor Site Criteria."

NRC Generic Letter 88-20, Supplement 4.

NFPA 820

1995 Edition

Standard for Fire Protection in Wastewater Treatment and Collection Facilities

1995 Edition

This edition of NFPA 820, *Standard for Fire Protection in Wastewater Treatment and Collection Facilities,* was prepared by the Technical Committee on Wastewater Treatment Plants and acted on by the National Fire Protection Association, Inc., at its Annual Meeting held May

22-25, 1995, in Denver, CO. It was issued by the Standards Council on July 21, 1995, with an effective date of August 11, 1995, and supersedes all previous editions.

This edition of NFPA 820 was approved as an American National Standard on August 11, 1995.

Origin and Development of NFPA 820

The Committee on Wastewater Treatment Plants was organized in 1983 to have primary responsibility for documents on safeguarding against the fire and explosion hazards specific to wastewater treatment plants and associated collection systems. This includes the hazard classification of specific areas and processes. The need to develop NFPA 820 was based on fire or explosion incidents that, while infrequent, are relatively severe when they do occur. Initial work on the document was begun early in 1985 and resulted in the first edition being issued in 1990. Extensive changes were made between the first edition and the 1992 edition, with the most notable revision being the document title, which was changed from Recommended Practice for Fire Protection in Wastewater Treatment Plants to Recommended Practice for Fire Protection in Wastewater Treatment and Collection Facilities. In addition, the document scope was revised to include storm sewer systems and their appurtenances.

In 1995 the document was changed from a recommended practice to a standard, which contains mandatory requirements. This was done because NFPA 820 was widely referenced by various jurisdictions.

Technical Committee on Wastewater Treatment Plants

James F. Wheeler, *Chair*
U.S. Environmental Protection Agency, DC

Alphonse A. Abadir, U.S. Dept. of Labor, DC

John R. Anderson, Marshfield, MA

Alonza W. Ballard, Crouse-Hinds ECM, NY
Rep. Nat'l Electrical Mfrs. Assn.

Alan J. Callier, Burns & McDonnell, MO
Rep. Water Environment Federation

Smith Choi, Metropolitan Water District of S California, CA

Michael P. Dyrness, Johnson and Higgins, WA

Jeffrey I. Enyart, American Concrete Pipe Assn., VA

Richard D. Gottwald, Society of the Plastics Industry, DC

John N. Harrell, Wilson & Co., Engr & Architects, KS

Gary Hewitt, The Gorman-Rupp Co., OH
Rep. Water & Wastewater Equip Mfrs. Assn, Inc

Garr M. Jones, Brown and Caldwell, CA

Edward S. Krupinski, Marsh & McLennan, Inc., AZ

Charles E. Kudla, Underwriters Laboratories Inc., NC

Paul A. Kuhn, Greeley and Hansen, IL

James Retzloff, The Viking Corp., MI
Rep. Nat'l Fire Sprinkler Assn.

Joseph P. Sheahan, Metro Water Reclamation District of Greater Chicago, IL
Rep. Assn. of Metropolitan Sewerage Agencies

Edward Sikora, Nat'l Clay Pipe Inst., WI

Dao T. Ton, Metropolitan Waste Control Commission, MN

John Wichmann, Burks Pumps, Inc., OH

Alternates

Josiah W. Beakley, American Concrete Pipe Assn., VA
(Alt. to J. I. Enyart)

James D. Lake, Nat'l Fire Sprinkler Assn., NY
(Alt. to J. Retzloff)

Daniel P. Ryan, Underwriters Laboratories Inc., NC
(Alt. to C. E. Kudla)

Ralph S. Thomas, Metropolitan Waste Control Commission, MN
(Alt. to D. T. Ton)

Casey C. Grant, NFPA Staff Liaison

This list represents the membership at the time the Committee was balloted on the text of this edition. Since that time, changes in the membership may have occurred.

NOTE: Membership on a Committee shall not in and of itself constitute an endorsement of the Association or any document developed by the Committee on which the member serves.

Committee Scope: This Committee shall have primary responsibility for documents on criteria for safeguarding against the fire and explosion hazards specific to wastewater treatment plants and associated collection systems, including the hazard classification of specific areas and processes.

NFPA 820

Standard for
Fire Protection in Wastewater Treatment and Collection Facilities

1995 Edition

NOTICE: An asterisk (*) following the number or letter designating a paragraph indicates explanatory material on that paragraph in Appendix A.
Information on referenced publications can be found in Chapter 9 and Appendix F.

Chapter 1 Introduction

1-1 Scope.

1-1.1 General.

1-1.1.1* This standard provides the minimum requirements for protection against fire and explosion hazards in wastewater treatment plants and associated collection systems, including the hazard classification of specific areas and processes.

1-1.1.2 This standard covers the following:

(a) Collection sewers,

(b) Trunk sewers,

(c) Intercepting sewers,

(d) Combined sewers,

(e) Storm sewers,

(f) Pumping stations,

(g) Wastewater treatment plants,

(h) Sludge-handling facilities,

(i) Chemical-handling facilities,

(j) Treatment facilities, or

(k) Ancillary structures (*see definition*).

1-1.1.3 This standard does not cover the following:

(a) Collection, treatment, or disposal of industrial wastes or manufactured by-products that are treated on-site and not discharged to a public or privately operated municipal facility;

(b) On-site treatment systems (*see definition*);

(c) Pressure sewer systems (*see definition*);

(d) Building drain systems and appurtenances (*see definition*);

(e) Industrial sewer systems and appurtenances (*see definition*);

(f) Personnel safety from toxic and hazardous materials or products of combustion; or

(g) Separate nonprocess related structures (*see definitions*).

1-1.2 Alternative Methods.

Nothing in this standard is intended to prevent or discourage the use of alternative methods, materials, practices, or devices, provided that sufficient technical data are submitted to the authority having jurisdiction to demonstrate that the alternative method, material, practice, or device is equivalent to or superior to the requirements of this standard.

1-1.3

A fire risk evaluation shall be initiated early in the facility design or alteration to integrate the fire prevention and fire protection requirements as described in this document.

1-2 Purpose.

1-2.1 General.

The purpose of this standard is to provide a reasonable degree of fire and explosion protection for life, property, continuity of mission, and protection of the environment. This standard intends to reduce or eliminate effects of fire or explosion by maintaining structural integrity, controlling flame spread and smoke generation, preventing the release of toxic products of combustion, and maintaining serviceability and operation of the facility.

1-2.2 Toxicity and Biological Hazards.

This standard addresses the fire and explosion hazards of various substances associated with wastewater treatment and conveyance. This standard does not cover toxicity and biological hazards.

CAUTION: It is recognized that, from a personnel safety standpoint, these hazards can be present in life-threatening concentrations while no threat of fire or explosion exists.

1-2.3 Ventilation Practices.

Ventilation rates required by this standard are intended to minimize fire and explosion hazards but might be insufficient to protect personnel from exposure to toxic and biological hazards.

1-2.4 Materials Selection.

The fire risk evaluation shall include consideration for flame spread, smoke generation, and the impact that a fire or explosion will have on the structural integrity of the facility when conditions or applications warrant the selection of materials that are combustible, limited combustible, or low flame spread.

CAUTION: Since many of the corrosion-resistant materials and coatings are combustible or limited-combustible and might represent a considerable fuel load during fire events, the design and fire risk evaluation shall consider any additional hazards imposed by the use of these materials.

1-3 Application.

1-3.1*

The requirements of this standard are intended for new installations. When additions or modifications are made to existing facilities, the modifications shall reflect the requirements of this document. In any event, the requirements of this standard shall be used by owners in a risk assessment to identify areas of a treatment plant that are vulnerable to fire or other loss.

1-3.2

This document is divided into 9 chapters. Chapters 1, 5, 6, 7, 8, and 9 apply generally. Chapters 2, 3, and 4 apply to specific processes and functions. The appendixes provide explanatory information, and the paragraph designations used in Appendix A coincide with the paragraph numbers used in Chapters 1 through 8 to which the clarification is provided. Appendix B provides a general overview and layout of the unit processes found at a typical wastewater treatment plant, although the arrangement of the unit processes will vary from plant to plant.

1-3.3* National Electrical Code® Criteria.

This standard is based on the criteria established by Article 500 of NFPA 70, *National Electrical Code*, but is not intended to supersede or conflict with the requirements therein. Once an area is properly classified, the *National Electrical Code* specifies the types of equipment and the wiring methods that shall be used.

1-4 Metric Units of Measurement Guidance.

Metric units of measurement used within this standard are in accordance with the modernized metric system known as the International System of Units (SI). Values of measurement are followed by an approximate equivalent value in SI units. For metric conversion practices, see ANSI/IEEE 268, *Metric Practices.*

1-5 Definitions.

Activated Carbon. Adsorptive carbon particles or granules usually obtained by heating carbonaceous material in the absence of air or in steam and possessing a high capacity to selectively remove trace and soluble components from solution.

Activated Sludge. A microbial mass grown in aeration tanks, subsequently separated from treated wastewater by sedimentation, and wasted or returned to the process as needed.

Adjacent. Adjacent, as used in this document, means sharing a common wall, partition, or barrier.

Advanced (Tertiary) Wastewater Treatment. Any physical, chemical, or biological treatment process used to accomplish a degree of treatment greater than that achieved by secondary treatment. (*See Secondary Wastewater Treatment.*)

Anaerobic Digestion. A unit process designed to biologically convert organic matter (sludge) through the action of microorganisms in the absence of elemental oxygen. Process by-products include a gas containing methane, carbon dioxide, and small quantities of hydrogen sulfide. The digestion tank can have a fixed or floating roof system.

Anaerobic Waste Treatment. A unit process providing treatment of the liquid stream by action of microorganisms in the absence of elemental oxygen. Process by-products include a gas containing methane, carbon dioxide, and small quantities of hydrogen sulfide.

Ancillary Structure. A structure that is an integral part of the wastewater treatment or collection process.

Approved.* Acceptable to the authority having jurisdiction.

Authority Having Jurisdiction.* The organization, office, or individual responsible for approving equipment, an installation, or a procedure.

Belt Filter. A sludge dewatering or concentrating device having continuous bands or belts of filtering media that pass around rollers and from which the material caught on the media is usually removed by gravity and pressure.

Building. A structure used or intended for supporting or sheltering any use or occupancy. Personnel might occupy buildings continuously or intermittently.

Building Drain. In plumbing, the part of the lowest horizontal piping of a drainage system that receives the discharge from soil, waste, and other drainage pipes inside the walls of the building and conveys it to the building sewer (house connection or lateral).

Centrifuge. A mechanical device in which centrifugal force is used to separate solids from liquids or to separate liquids of different densities.

Combustible. Any material that does not comply with the definition of either noncombustible or limited-combustible.

Combustible Gas Detectors. Devices used to detect the presence of flammable vapors and gases and warn when concentrations in air approach the explosive range.

Combustible Liquid. A liquid having a flash point at or above 100°F (37.8°C). (*See NFPA 30, Flammable and Combustible Liquids Code*.)

Combustible or Explosive Dust. A dust capable of spontaneous combustion or of exploding or burning when subjected to a source of ignition.

Compost. The product of thermophilic biological oxidation of sludge or other organic materials.

Digester Gas. See Sludge Gas.

Dissolved Air Flotation. A separation process in which air bubbles emerging from a supersaturated solution become attached to suspended solids in the liquid undergoing treatment and float them up to the surface.

Domestic Wastewater. Wastewater derived principally from dwellings, commercial establishments, institutions, and the like. It might or might not contain small amounts of ground water, surface water, or storm water.

Dry Well. That portion of a pumping station designed to provide isolation and shelter or accommodations for controls or equipment associated with pumping of wastewater. Dry wells are designed to completely and permanently exclude wastewater or wastewater-derived atmospheres. Dry wells can contain accidental leakage of wastewater from shaft seals or occasional spills. A dry well might contain equipment such as pumps, motors, fans, wiring, controls, lights and associated wiring devices, and other accessories.

Drying Beds. Confined, underdrained, shallow layers of sand or gravel on which digested sludge is distributed for draining and air drying. Also applied to underdrained, shallow, diked earthen structures used for drying sludge.

Enclosed. The interior of any tank or unit process that is closed to the atmosphere (excluding vents or pressure relief), or the area around any open tank or unit process surrounded by a building or other structure constructed with a roof and solid walls.

Equipment. A general term including material, fittings, devices, appliances, fixtures, apparatus, and the like used as part of, or in connection with, a mechanical, instrumentation, or electrical installation.

Equipment Enclosure. The housing that covers, protects, or guards a piece of equipment and is not intended for personnel occupancy, but can provide for access to the equipment.

Explosionproof Apparatus. Apparatus, enclosed in a case, that is capable of withstanding an explosion of a specified gas or vapor that might occur within it and of preventing the ignition of a specified gas or vapor surrounding the enclosure by sparks, flashes, or explosion of the gas or vapor within and that operates at such an external temperature that a surrounding flammable atmosphere will not be ignited thereby.

Explosive Limits. The minimum concentration of a gas-air or vapor-air mixture that supports flame, if ignited, is known as the lower explosive limit (LEL). The maximum concentration of a gas-air or vapor-air mixture that, if ignited, supports flame is known as the upper explosive limit (UEL). Above the UEL and below the LEL, ignition cannot take place. (These values might change in oxygen-enriched atmospheres.)

Filter (Pressure or Gravity). A device used to pass liquid through a medium to remove suspended solids.

Filter Press. A unit process using a plate and frame press, that is operated hydraulically and mechanically, to produce a semisolid sludge cake from a slurry.

Fire Barrier. A continuous membrane, either vertical or horizontal, such as a wall or floor assembly, that is designed and constructed with a specified fire resistance rating to limit the spread of fire and that will also restrict the movement of smoke. Such barriers might have protected openings.

Fire Loading. The amount of combustibles present in a given area, expressed in Btu/ft^2 (kJ/m^2).

Fire Prevention. Measures directed toward avoiding the inception of fire.

Fire Protection. Methods of providing for fire control or fire extinguishment.

Fire-Rated Penetration Seal. An opening in a fire barrier for the passage of pipe, cable, duct, etc., that has been sealed so as to maintain a barrier rating.

Fire Resistance Rating. The time, in minutes or hours, that materials or assemblies have withstood a fire exposure as established in accordance with the test procedures of NFPA 251, *Standard Methods of Tests of Fire Endurance of Building Construction and Materials*. This definition applies to the materials used in the construction of buildings but does not apply to furnishings or the contents of buildings or to the fire hazard evaluation of materials.

Fire Stop. A through-penetration fire stop is a specific construction consisting of the materials that fill the opening around penetrating items such as cables, cable trays, conduits, ducts, and pipes and their means of support through the wall or floor opening to prevent spread of fire. Its rating is established in accordance with test procedures in ASTM E 814, *Standard Method of Fire Tests of Through-Penetration Fire Stops.*

Flammable Liquid. Any liquid having a flash point below 100°F (37.8°C) and having a vapor pressure not exceeding 40 psia (276 kPa) absolute pressure at 100°F (37.8°C). (*See NFPA 30, Flammable and Combustible Liquids Code*.)

Flash Dryer. A device for vaporizing water from partly dewatered and finely divided sludge through contact with a current of hot gas or superheated vapor. It includes a squirrel-cage mill for separating the sludge cake into fine particles.

Flash Mixer. A device for quickly dispersing chemicals uniformly throughout a liquid or semisolid.

Flocculator. A unit process for the formation of floc in wastewater.

Fluidized Bed Reactor. A pressure vessel or tank that is designed for liquid-solid or gas-solid reaction; the liquid or gas moves upward through the solids particles at a velocity sufficient to suspend the individual particles in the fluid. Applications include ionexchange, granular activated carbon adsorbers, and some types of furnaces, kilns, and biological contactors.

Force Main (Pressure Main). A pressure pipe connecting the pump discharge of a wastewater pumping station under pressure to a point of discharge.

Fuel Gases. Any gas used as a fuel source including natural gas, manufactured gas, sludge gas, liquefied petroleum gas-air mixtures, liquefied petroleum gas in the vapor phase, and mixtures of these gases. (*See NFPA 54, National Fuel Gas Code*.)

Galleries. Long tunnels or walkways connecting separate buildings or structures. Galleries are generally underground, without windows, and with limited entrances and exits. Galleries frequently contain gas, water, wastewater, sludge piping, electrical wiring, and mechanical or electrical equipment.

Gas-Handling Equipment. Gas-handling equipment includes equipment for removal of gas evolved from the anaerobic digestion process and the compression, conditioning, or treatment of this gas. This equipment includes gas compressors, sediment traps, drip traps, gas scrubbers, and pressure regulating and control valves. Gas-handling equipment does not include equipment or devices for the utilization of the gas, such as boilers, engines, and waste gas burners.

Grit Chamber. A detention chamber or an enlargement of a sewer designed to reduce the velocity of flow of the liquid to permit the separation of mineral from organic solids by differential sedimentation.

Hazardous (Classified) Location. Locations are classified depending on the properties of the flammable vapors, liquids, or gases or combustible dusts or fibers that might be present and the likelihood that a flammable or combustible concentration or quantity is present. Each room, section, or area is considered individually in determining its classification.

Hazardous Waste. Any waste that is potentially damaging to the environment or human health because of toxicity, ignitibility, corrosivity, chemical reactivity, or other reason.

Heat Treatment. A sludge-conditioning process combining high temperature, time, and pressure to improve the dewaterability of organic sludge.

Hydrogen Sulfide (H_2S). A toxic and lethal gas produced in sewers and digesters by anaerobic decomposition of wastewater solids or other anaerobic wastewater or sludge treatment processes.

Identified (as applied to equipment). Recognizable as suitable for the specific purpose, function, use, environment, application, etc., where described in a particular code requirement. Suitability of equipment for a specific purpose, environment, or application can be determined by a qualified testing laboratory, inspection agency, or other organization concerned with product evaluation. Such identification can include labeling or listing. (*See Labeled and Listed*.)

Imhoff Tank. A deep, two-story wastewater treatment tank. It consists of an upper continuous-flow sedimentation chamber and a lower sludge-digestion chamber. The upper chamber floor slopes steeply to trapped slots through which solids can slide into the lower chamber. The lower chamber receives no fresh wastewater directly but is provided with gas vents and with means for drawing digested sludge from near the bottom.

Incineration. Combustion or controlled burning of volatile organic matter in sludge and solid waste that reduces the volume of the material while producing heat, dry inorganic ash, and gaseous emissions.

Industrial Waste. Generally liquid, solid, or gaseous wastes originating from the manufacture of specific products. Such wastes are usually more concentrated, are more variable in content and rate, and require more extensive or different treatment than municipal waste.

Inspection. A visual examination of a system or portion thereof to verify that it appears to be in operating condition and is free of physical damage.

Intrinsically Safe. Intrinsically safe equipment and wiring are not capable of releasing sufficient electrical or thermal energy under normal or abnormal conditions to cause ignition of a specific flammable or combustible atmospheric mixture in its most easily ignitable concentration. Abnormal conditions include accidental damage to any field-installed wiring, failure of electrical components, application of overvoltage, adjustment and maintenance operations, and other similar conditions. (*See ANSI/ISA RP 12.67, Installation of Intrinsically Safe Instrument Systems in Class I Hazardous Locations*.)

Labeled. Equipment or materials to which has been attached a label, symbol, or other identifying mark of an organization that is acceptable to the authority having jurisdiction and concerned with product evaluation that maintains periodic inspection of production of labeled equipment or materials and by whose labeling the manufacturer indicates compliance with appropriate standards or performance in a specified manner.

Limited-Combustible. As applied to a building construction material, a material not complying with the definition of noncombustible material that in the form in which it is used has a potential heat value not exceeding 3500 Btu/lb (8.14×10^6 J/kg) (*see NFPA 259, Standard Test Method* *for Potential Heat of Building Materials*) and complies with one of the following paragraphs (a) or (b):

(a) Materials having a structural base of noncombustible material with a surfacing not exceeding a thickness of $^1/_8$ in. (3.175 mm) that has a flame spread rating not greater than 50.

(b) Materials, in the form and thickness used, other than as described in (a), having neither a flame spread rating greater than 25 nor evidence of continued progres- sive combustion and of such composition that surfaces that would be exposed by cutting through a material on any plane would have neither a flame spread rating greater than 25 nor evidence of continued progressive combustion as tested in accordance with NFPA 255, *Standard Method of Test of Surface Burning Characteristics of Building Materials*.

NOTE: Materials subject to increase in combustibility or flame spread rating beyond the limits herein established through the effects of age, moisture, or other atmospheric condition should be considered combustible. This definition applies to the materials used in the construction of buildings but does not apply to furnishings or the contents of buildings or to the fire hazard evaluation of materials.

Listed.* Equipment or materials included in a list published by an organization acceptable to the authority having jurisdiction and concerned with product evaluation that maintains periodic inspection of production of listed equipment or materials and whose listing states either that the equipment or material meets appropriate standards or has been tested and found suitable for use in a specified manner.

Low Flame Spread. A material with a flame spread rating of 25 or less when classified in accordance with NFPA 255, *Standard Method of Test of Surface Burning Characteristics of Building Materials*.

Maintenance. Work performed to keep equipment operable or to make repairs.

Maintenance Hole. A structure atop an opening in a gravity sewer to permit personnel entry, or an opening in the top or side of an enclosed vessel to permit personnel entry. Also referred to as manhole or manway.

Methane (CH_4). A colorless, odorless, flammable gaseous hydrocarbon present in natural gas and formed by the anaerobic decomposition of organic matter. (*See also Anaerobic Digestion.*)

Nitrification Tank. A unit process for the oxidation of ammonia and nitrogen into nitrates through biochemical actions.

Noncombustible. A material that in the form in which it is used and under the conditions anticipated will not aid combustion or add appreciable heat to an ambient fire. Materials when tested in accordance with ASTM E 136, *Standard Test Method for Behavior of Materials in a Vertical Tube Furnace at 750°C (1382°F)*, and conforming to the criteria contained in Section 7 of the referenced standard shall be considered as noncombustible. This definition applies to the materials used in the construction of buildings but does not apply to furnishings or the contents of buildings or to the fire hazard evaluation of materials.

Nonenclosed. Any tank or unit process open to the atmosphere, or the area around any open tank or unit process housed in a building or other structure constructed with a roof and having at least 50 percent of the wall area open to the atmosphere. Fixed open louvered panels with effective openings greater than 50 percent of the wall area and evenly distributed over the wall area are considered open to the atmosphere.

On-Site Treatment System. A self-contained system, including pumping equipment, that provides both treatment and disposal of wastewater on or immediately adjacent to a single residence or group of residences or small commercial establishments.

Oxygen-Enriched Atmosphere. Any atmosphere with an oxygen concentration greater than ambient by volume at normal atmospheric pressure, for example in oxygen-activated sludge systems, ozonation units, or high-pressure oxidation units.

Ozonation. The process of contacting wastewater or air with ozone for the purpose of disinfection, oxidation, or odor control.

Physically Separated. Physically separated, as used in this document, means a gastight partition between two adjacent spaces, or two nonadjacent spaces, with no means of gas communication between the spaces. Personnel entry to the separate spaces is by individual, grade-level exterior access ports with no physical connection between the two.

Primary Wastewater Treatment. The first major treatment in a wastewater treatment plant, generally consisting of one or more of the following unit processes: screening, comminution or grinding, grit removal, sedimentation, and skimming.

Pumping Station. A structure that contains pumps and appurtenant piping, valves, and other mechanical and electrical equipment for pumping wastewater or other liquid. Also called lift station.

Pyrolysis. The destructive distillation of organic compounds in an oxygen-free environment that converts the organic matter into gases, liquids, and char.

Residential Wastewater. Wastewater derived from areas consisting of single- and multiple-family residences.

Rotating Biological Contactor (RBC). A unit process for wastewater treatment that is composed of large, closely spaced plastic discs that are rotated about a horizontal shaft (usually a secondary biological treatment process).

Screening Chamber. A chamber or enlargement of a sewer where large suspended or floating solids or material is removed from raw wastewater by a screen.

Scum or Skimmings. Grease, solids, liquids, and other floatable material removed from settling tanks.

Secondary Wastewater Treatment. Wastewater treatment unit processes usually consisting of primary treatment and biological oxidation using activated sludge or trickling filtration, followed by clarification.

Sedimentation. The unit process of subsidence of suspended matter carried by water, wastewater, or other liquids, by gravity. It is usually accomplished by reducing the velocity of the liquid below the point at which it can transport the suspended material. Also called settling, it can be enhanced by chemical addition, coagulation, and flocculation.

Separate Nonprocess-Related Structures. Structures that are physically separated and do not contain any process-related equipment associated with the collection and treatment of wastewaters and solids derived from wastewater treatment processes.

Sewer. A single pipe or system of pipes or conduits that carries wastewater or drainage water. See definitions below for different types of sewers.

Branch. A sewer that receives wastewater from a relatively small area and discharges into a main sewer serving more than one branch-sewer area.

Building. In plumbing, the extension from the building drain to the public sewer or other place of disposal (also called house connection or lateral).

Collector. A pipe or conduit that receives wastewater from a relatively small area from two or more lateral sewers and that subsequently discharges into a trunk sewer.

Combined. A sewer intended to receive both wastewater and storm or surface water.

Industrial. A sewer intended to receive only industrial wastewater or other liquid or water-carried wastes (also see sanitary sewer, storm sewer, and combined sewer).

Interceptor. A sewer that receives dry-weather flow and frequently additional predetermined quantities of storm water (if from a combined system) from a number of transverse sewers or outlets and conducts such waters to a point for treatment or disposal (also called main sewer).

Outfall. A sewer that receives wastewater from a collecting system or from a treatment plant and carries it to a point of final discharge.

Pressure. A collection sewer that incorporates a wastewater grinder pump or septic tank effluent pump to convey wastewater from a single residence or group of residences or small commercial establishments to a private or public sewer system or on-site disposal system.

Private. A sewer privately owned and used by one or more properties or owners.

Relief. A sewer built to carry the flows in excess of the capacity of an existing sewer. Also a sewer intended to carry a portion of the flow from a district in which the existing sewers are of insufficient capacity.

Residential. A sewer intended to receive only residential wastewater (also see combined sewer, sanitary sewer, and storm sewer).

Sanitary. A sewer that carries liquid and water-carried wastes from residences, commercial buildings, industrial plants, and institutions together with minor quantities of storm, surface, and ground waters that are not admitted intentionally.

Storm. A pipe or conduit that carries storm water and surface water, street wash, and other wash water, or drainage, but excludes domestic wastewater and industrial wastes (also called storm drain).

Trunk. The principal pipe or conduit to which one or more collector sewers or branch sewers are tributaries (also called main sewer).

Sewer Gas. Gas resulting from decomposition of organic matter in wastewater in sewers. Also, gas resulting from the incidental uncontrolled release of hydrocarbons or decomposition of organic matter in stagnant liquid and septic sludge in wastewater treatment plants. The gas might contain trace quantities of methane and hydrogen sulfide and might be low in oxygen. It might be both a fire and life safety hazard.

Shall. Indicates a mandatory requirement.

Sludge. A semiliquid mass of accumulated settled solids deposited from wastewater, raw or treated, in tanks or basins. Also referred to as biosolids.

Sludge Cake. A semisolid product of a sludge dewatering process.

Sludge Dewatering. The process of removing a part of the water in sludge by any physical or mechanical method without heat, such as draining, pressing, vacuum filtration, centrifuging, or passing between rollers.

Sludge Drying Systems. Sludge processes using physical or mechanical evaporation techniques with or without the application of heat to achieve solids concentrations greater than 85 percent.

Sludge Gas. Gas obtained as a by-product of the anaerobic sludge digestion unit process from the decomposition of organic matter. It has a high content of methane, varying amounts of carbon dioxide and hydrogen sulfide, and a small amount of nitrogen. It can be both a fire and life safety hazard.

Sludge Gas Vent. A passage to permit the controlled release of gases from anaerobic treatment processes or gas storage facilities.

Sludge Thickening. A sludge treatment process designed to concentrate wastewater sludges by gravity, mechanical means, or air flotation.

Sludge Treatment. The processing of wastewater sludges to render them stable. This can be done by aerobic or anaerobic digestion followed by drying on sand beds, filtering and incineration, filtering and drying, or wet air oxidation.

Standard. A document, the main text of which contains only mandatory provisions using the word “shall” to indicate requirements, which is in a form generally suitable for mandatory reference by another standard or code or for adoption into law. Nonmandatory provisions shall be located in an Appendix, footnote, or fine-print note and are not to be considered a part of the requirements of a standard.

Structure. Structure, as used in this document, includes all construction designed to carry gravity loads and intended to contain wastewater, sludge, sludge gas, piping, or equipment. Structures can provide access but are not intended for continuous personnel occupancy.

Trickling Filter. A treatment unit process consisting of stone, plastic, redwood, or similar media over which wastewater is distributed and through which wastewater trickles to the underdrains and is treated by the microbial slimes formed on the surface of the media.

Utilization Equipment. Equipment that utilizes electric energy for mechanical, chemical, heating, lighting, or similar purposes.

Vacuum Filter. A unit process used to dewater wastewater sludge and consisting of a cylindrical drum mounted on a horizontal axis, covered with a media, and subjected to an internal vacuum.

Vault. An enclosed structure, usually underground, used to permit personnel access to various types of equipment and instrumentation.

Ventilation Rate. Ventilation rate, as used in this document, is based on air changes per hour and is calculated by the use of 100 percent outside air for the supply air that is exhausted. Air change per hour is calculated on the basis of the maximum aggregate volume (under normal operating conditions) of the space to be ventilated.

Volatile Liquid. A liquid that evaporates readily at normal temperature and pressure.

Wastewater. The spent water of a community. Combination of the liquid and water-carried wastes from residences, commercial buildings, industrial plants, and institutions, together with any ground water, surface water, and storm water that might be present.

Wet Well. That portion of the pumping station that receives and temporarily stores wastewater for the purpose of pumping. A wet well might or might not contain electrical equipment such as pumps, motors, fans, wiring and wiring devices, controls, lights, and other accessories.

Chapter 2 Collection Systems

2-1* General.

This chapter provides minimum criteria for protection against fire and explosion hazards in the collection and transportation of municipal wastewater. This chapter does not address on-site systems, force mains, or those sewers that convey principally industrial wastes. Table 2 summarizes the various components associated with wastewater collection and transport systems.

2-2* Design and Construction.

The design and construction of collection system facilities shall conform to Table 2.

Table 2 Collection Systems

		A	B	C	D	E	F	G
		Location and Function	Fire and Explosion Hazard	Ventilation	Extent of Classified Area	NEC-Area Electrical Classification (All Class I, Group D)	Material of Construction for Buildings or Structures	Fire Protection Measures
1		MATERIALS USED IN REHABILITATION, RECONSTRUCTION, OR SLIP-LINING OF SEWERS	NA	NA	NA	NA	In accordance with 6-3.1	NA
2		INDUSTRIAL SEWER Sewer transporting industrial wastewater only. (No sanitary wastewater.)	Not included within the scope of this document					
3		STORM SEWER Sewer transporting storm water only. (No sanitary wastewater.)	Possible ignition of flammable gases and floating flammable liquids	NNV	Inside of sewer	Division 2	In accordance with 6-3.1	NR
4		STORM WATER PUMPING STATION WET WELLS Liquid side of pumping station serving only a storm sewer system.	Possible ignition of flammable gases and floating flammable liquids	NNV	Entire room or space	Division 2	NC, LC, or LFS	CGD if enclosed
5	a	STORM WATER PUMPING STATION DRY WELLS Dry side of a pumping station serving only a storm sewer system and physically separated from wet well.	Buildup of vapors from flammable or combustible liquids	D	Entire dry well	Division 2, or unclassified, if space provided with pressurization in accordance with NFPA 496	NC, LC, or LFS	FE
	b			C		Unclassified		
6		PRESSURE SEWER- (Force main) Sewer under pressure. (Flooded discharge pipe from pump or tank.)	Not included within the scope of this document					
7		BUILDING SEWER (Lateral sewer or drain) Sewer serving a house or single building (plumbing).	Not included within the scope of this document					
8		INDIVIDUAL RESIDENTIAL SEWER Sewer serving one but not more than five dwellings.	NA	NNV	Within enclosed space	Unclassified	NR	NR
9		INDIVIDUAL RESIDENTIAL PUMPING UNITS Pumping units serving one but not more than five dwellings (e.g., grinder pumps, septic tank effluent pumps, ejector pumps).	NA	NNV	Within enclosed space	Unclassified	NR	NR

A — No ventilation, or ventilated at less than 12 air changes per hour
B — Continuously ventilated at 12 air changes per hour or in accordance with Chapter 7
C — Continuously ventilated at 6 air changes per hour or in accordance with Chapter 7
CGD — Combustible gas detection system
FE — Portable fire extinguisher
FSS — Fire suppression system (automatic sprinkler, water spray, foam, gaseous, or dry chemical)
H — Hydrant protection in accordance with 5-2.4
LC — Limited-combustible material
LFS — Low flame spread material
NA — Not applicable
NR — No requirement

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Table 2 (continued)

		A	B	C	D	E	F	G
		Location and Function	Fire and Explosion Hazard	Ventilation	Extent of Classified Area	NEC-Area Electrical Classification (All Class I, Group D)	Material of Construction for Buildings or Structures	Fire Protection Measures
10	a	RESIDENTIAL SEWER Sewer transporting primarily residential wastewater.	Possible ignition of flammable gases and floating flammable liquids	NNV	Within enclosed space	Division 2	In accordance with 6-3.1	NR
	b			B		Unclassified		
11	a	RESIDENTIAL WASTEWATER PUMPING STATION WET WELL. Pumping station transporting primarily residential wastewater.	Possible ignition of flammable gases and floating flammable liquids	A	Entire room or space	Division 2	NC, LC, or LFS	CGD
	b			B		Unclassified		
12	a	RESIDENTIAL WASTEWATER PUMPING STATION DRY WELL Dry side of a pumping station transporting primarily residential wastewater.	Buildup of vapors from flammable or combustible liquids	D	Entire room or space	Division 2	NC, LC, or LFS	FE
	b			C		Unclassified		
13		OUTFALL SEWER Final discharge pipe, from a treatment plant, transporting treated wastewater.	NA	NNV	NA	Unclassified	NR	NR
14	a	SANITARY SEWER Sewer transporting domestic, commercial, and industrial wastewater.	Possible ignition of flammable gases and floating flammable liquids	NNV	Inside of sewer	Division 1	In accordance with 6-3.1	NR
	b			B		Division 2		
15	a	COMBINED SEWER Sewer transporting domestic, commercial, and industrial wastewater and storm water.	Possible ignition of flammable gases and floating flammable liquids	NNV	Inside of sewer	Division 1	In accordance with 6-3.1	NR
	b			B		Division 2		
16	a	WASTEWATER PUMPING STATION WET WELLS Liquid side of a pumping station serving a sanitary sewer or combined system.	Possible ignition of flammable gases and floating flammable liquids	A	Entire room or space	Division 1	NC, LC, or LFS	CGD
	b			B		Division 2		
17	a	BELOW- OR PARTIALLY BELOW-GRADE WASTEWATER PUMPING STATION DRY WELL. Pump room physically separated from wet well. Pumping of wastewater from a sanitary or combined sewer system through closed pumps and pipes.	Buildup of vapors from flammable or combustible liquids	C	Entire space or room	Unclassified	NC, LC, or LFS	FE
	b			D		Division 2, or unclassified, if space provided with pressurization in accordance with NFPA 496		

A — No ventilation, or ventilated at less than 12 air changes per hour
B — Continuously ventilated at 12 air changes per hour or in accordance

FSS — Fire suppression system (automatic sprinkler, water spray, foam, gaseous, or dry chemical)

D — No ventilation, or ventilated at less than 6 air changes per hour
FAS — Fire alarm system
FDS — Fire detection system
FE — Portable fire extinguisher

NC — Noncombustible material
NEC — In accordance with NFPA 70, *National Electrical Code*
NNV — Not normally ventilated
NR — No requirement

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Table 2 (continued)

		A	B	C	D	E	F	G
		Location and Function	**Fire and Explosion Hazard**	**Ventilation**	**Extent of Classified Area**	**NEC-Area Electrical Classification (All Class I, Group D)**	**Material of Construction for Buildings or Structures**	**Fire Protection Measures**
18		ABOVE-GRADE WASTE-WATER PUMPING STATION Pump room physically separated with no personnel access to wet well. Pumping of wastewater from a sanitary or combined sewer system through closed pumps and pipes.	NA	NR	NA	Unclassified	NC, LC, or LFS	FE
19	a	ABOVE-GRADE WASTE-WATER PUMPING STATION Pump room not physically separated from wet well. Pumping of wastewater from a sanitary or combined sewer system through closed pumps and pipes.	Possible ignition of flammable gases and floating flammable liquids	A	Entire space or room	Division 1	NC	FE
	b			B		Division 2	NC, LC, or LFS	
20	a	ODOR CONTROL SYSTEM AREAS Areas physically separated from wet well that house systems handling wet well gases	Leakage and ignition of sewage gases	D	Entire area if enclosed	Division 2	NC, LC, or LFS	CGD and FDS
	b			C, or outdoors	Areas within 3 ft (0.9 m) of leakage sources such as fans, dampers, flexible connections, flanges, pressurized unwelded ductwork, and odor control vessels	Division 2		
	c				Areas beyond 3 ft (0.9 m)	Unclassified		
21	a	MAINTENANCE HOLES Access to sewer for personnel entry.	Possible ignition of flammable gases and floating flammable liquids	NNV	Inside	Division 1	In accordance with 6-3.1	NR
	b			B		Division 2		
22	a	JUNCTION CHAMBERS Structure where sewers intersect.	Buildup of vapors from flammable or combustible liquids	NNV	Inside	Division 1	In accordance with 6-3.1	NR
	b			B	Open and above grade or inside and ventilated	Division 2		
23		INVERTED SIPHONS Depressed section of gravity sewer.	Possible ignition of flammable gases and floating flammable liquids	NNV	Interior of inlet and outlet structures	Division 1	NC	NR

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FAS — Fire alarm system
FDS — Fire detection system
FE — Portable fire extinguisher

FSS — Fire suppression system (automatic sprinkler, water spray, foam, gaseous, or dry chemical)
H — Hydrant protection in accordance with 5-2.4
NEC — In accordance with NFPA 70, *National Electrical Code*
NNV — Not normally ventilated
NR — No requirement

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Table 2 (continued)

		A	B	C	D	E	F	G
		Location and Function	Fire and Explosion Hazard	Ventilation	Extent of Classified Area	NEC-Area Electrical Classification (All Class I, Group D)	Material of Construction for Buildings or Structures	Fire Protection Measures
24		CATCH BASINS (Curb inlet) Inlet where street water enters a storm or combined sewer.	Buildup of vapors from flammable or combustible liquids	NNV	Enclosed space	Division 1	In accordance with 6-3.1	NR
25	a	RESIDENTIAL DIVERSION STRUCTURES Enclosed structures where residential wastewater can be diverted.	Buildup of vapors from flammable or combustible liquids	NNV	Enclosed space	Division 2	In accordance with Chapter 6	NR
	b			B		Unclassified		
26	a	RESIDENTIAL BELOW-GRADE VALVE VAULT With an exposed residential wastewater surface.	Possible ignition of gases and floating flammable liquids	NNV	Enclosed space	Division 2	In accordance with 6-3.1	NR
	b			B		Unclassified		
27	a	RESIDENTIAL CONTROL STRUCTURES Enclosed structures where residential wastewater flow is regulated.	Buildup of vapors from flammable or combustible liquids	A	Enclosed space	Division 2	In accordance with Chapter 6	NR
	b			B		Unclassified		
28	a	RESIDENTIAL BELOW-GRADE METERING VAULT With an exposed residential wastewater surface.	Possible ignition of flammable gases and floating flammable liquids	NNV	Enclosed space	Division 2	In accordance with 6-3.1	NR
	b			B		Unclassified		
29	a	DIVERSION STRUCTURES Enclosed structures where wastewater can be diverted.	Buildup of vapors from flammable or combustible liquids	NNV	Enclosed space	Division 1	In accordance with Chapter 6	NR
	b			B		Division 2		
30		ABOVE-GRADE VALVE VAULT Physically separated from the wet well. Valves in vault in closed piping system.	NA	NR	NA	Unclassified	NC, LC, or LFS	NR
31	a	BELOW-GRADE VALVE VAULT Physically separated from the wet well and with closed piping system.	Buildup of vapors from flammable or combustible liquids	NNV	Enclosed space	Division 2	NC, LC, or LFS	NR
	b			C		Unclassified		
32	a	BELOW-GRADE VALVE VAULT With an exposed wastewater surface.	Possible ignition of gases and floating flammable liquids	NNV	Enclosed space	Division 1	NC	NR
	b			B		Division 2	NC, LC, or LFS	
33	a	CONTROL STRUCTURES Enclosed structures where wastewater or storm water flow is regulated.	Buildup of vapors from flammable or combustible liquids	A	Enclosed space	Division 1	In accordance with Chapter 6	NR
	b			B		Division 2		

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C — Continuously ventilated at 6 air changes per hour or in accordance with Chapter 7
CGD — Combustible gas detection system
D — No ventilation, or ventilated at less than 6 air changes per hour
FSS — Fire suppression system (automatic sprinkler, water spray, foam, gaseous, or dry chemical)
H — Hydrant protection in accordance with 5-2.4
LC — Limited-combustible material
LFS — Low flame spread material
NA — Not applicable
NC — Noncombustible material

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Table 2 (continued)

		A	B	C	D	E	F	G
		Location and Function	Fire and Explosion Hazard	Ventilation	Extent of Classified Area	NEC-Area Electrical Classification (All Class I, Group D)	Material of Construction for Buildings or Structures	Fire Protection Measures
34	a	WASTEWATER HOLDING BASINS Enclosed structures holding untreated or partially treated wastewater temporarily.	Possible ignition of flammable gases and floating flammable liquids	A	Enclosed space	Division 1	NC	NR
	b			B		Division 2	NC, LC, or LFS	
35		WASTEWATER HOLDING BASINS, LINED OR UNLINED Open structures holding storm water, combined wastewater, untreated or partially treated wastewater.	NR	NR	NR	NR	NR	NR
36	a	BELOW-GRADE METERING VAULT Physically separated from the wet well and with closed piping system.	Buildup of vapors from flammable or combustible liquids	NNV	Enclosed space	Division 2	NC, LC, or LFS	NR
	b			C		Unclassified		
37	a	BELOW-GRADE METERING VAULT With an exposed wastewater surface.	Possible ignition of flammable gases and floating flammable liquids	NNV	Enclosed space	Division 1	NC	NR
	b			B		Division 2	NC, LC, or LFS	
38		COARSE AND FINE SCREEN FACILITIES (*See Coarse and Fine Screen Facilities, Table 3.*)						

A — No ventilation, or ventilated at less than 12 air changes per hour
B — Continuously ventilated at 12 air changes per hour or in accordance with Chapter 7
C — Continuously ventilated at 6 air changes per hour or in accordance with Chapter 7
CGD — Combustible gas detection system
D — No ventilation, or ventilated at less than 6 air changes per hour
FAS — Fire alarm system
FDS — Fire detection system
FE — Portable fire extinguisher
FSS — Fire suppression system (automatic sprinkler, water spray, foam, gaseous, or dry chemical)
H — Hydrant protection in accordance with 5-2.4
LC — Limited-combustible material
LFS — Low flame spread material
NA — Not applicable
NC — Noncombustible material
NEC — In accordance with NFPA 70, *National Electrical Code*
NNV — Not normally ventilated
NR — No requirement

Chapter 3 Liquid Stream Treatment Processes

3-1* General.

This chapter provides minimum criteria for protection against fire and explosion hazards associated with liquid stream treatment processes. This chapter does not address treatment systems serving individual structures or treatment systems that treat principally industrial wastes. Table 3 summarizes the various components associated with liquid stream treatment processes.

3-2* Design and Construction.

The design and construction of liquid stream treatment processes shall conform to Table 3.

Table 3 Liquid Stream Treatment Processes

		A	B	C	D	E	F	G
		Location and Function	Fire and Explosion Hazard	Ventilation	Extent of Classified Area[3]	NEC-Area Electrical Classification (All Class I, Group D)	Material of Construction for Buildings or Structures	Fire Protection Measures
1	a	COARSE AND FINE SCREEN FACILITIES Removal of screenings from raw wastewater.	Possible ignition of flammable gases and floating flammable liquids	A	Enclosed — entire space	Division 1	NC	FE, H, and CGD if enclosed
	b			B		Division 2	NC, LC, or LFS	
	c			Not enclosed, open to atmosphere	Within 10 ft (3 m) envelope around equipment and open channel[1,2]			
2		PUMPING STATIONS (*See Collection Systems, Table 2.*)						
3	a	FLOW EQUALIZATION TANKS Storage of raw or partially treated wastewater.	Possible ignition of flammable gases and floating flammable liquids	A	Enclosed — entire space	Division 1	NC	FE, H, and CGD if enclosed
	b			B		Division 2	NC, LC, or LFS	
	c			Not enclosed, open to atmosphere	Within 10 ft (3 m) envelope around equipment and open channel[1,2]			
4	a	GRIT REMOVAL TANKS Separation of grit from raw wastewater.	Possible ignition of flammable gases and floating flammable liquids	A	Enclosed — entire space	Division 1	NC	FE, H, and CGD if enclosed
	b			B		Division 2	NC, LC, or LFS	
	c			Not enclosed, open to atmosphere	Within 10 ft (3 m) envelope around equipment and open channel[1,2]			
5	a	PRE-AERATION TANKS Conditioning of wastewater prior to further treatment.	Possible ignition of flammable gases and floating flammable liquids	A	Enclosed — entire space	Division 1	NC	H and CGD if enclosed
	b			B		Division 2	NC, LC, or LFS	
	c			Not enclosed, open to atmosphere	Within 10 ft (3 m) envelope around equipment and open channel[1]			
6	a	PRIMARY SEDIMENTATION TANKS Separation of floating or settleable solids from raw wastewater.	Possible ignition of flammable gases and floating flammable liquids	A	Enclosed — entire space	Division 1	NC	H and CGD if enclosed
	b			B		Division 2	NC, LC, or LFS	
	c			Not enclosed, open to atmosphere	Interior of the tank from the minimum operating water surface to the top of the tank wall. Envelope 18 in. (0.46 m) above the top of the tank and extending 18 in. (0.46 m) beyond the exterior wall. Envelope 18 in. (0.46 m) above grade extending 10 ft (3 m) horizontally from the exterior tank walls.			
7		AERATION BASIN, POND, LAGOON, OXIDATION DITCH, AEROBIC SUSPENDED GROWTH SYSTEMS, SEQUENCING BATCH REACTORS Aerobic treatment of wastewater open to the atmosphere.		NA		Unclassified (If process is not preceded by primary sedimentation, refer to primary sedimentation in Table 3 for classification.)	NR	H

NOTE 1: Area beyond envelope is unclassified.
NOTE 2: Where liquid turbulence is not induced by aeration or other factors, the following criteria apply: interior of the tank from the minimum operating water surface to the top of the tank wall; envelope 18 in. (0.46 m) above the top of the tank and extending 18 in. (0.46 m) beyond the exterior wall; and envelope 18 in. (0.46 m) above grade extending 10 ft (3 m) horizontally from the exterior tank walls.
NOTE 3: Open channels and open structures upstream from the unit processes are to be classified the same as the downstream process they supply.

A — No ventilation, or ventilated at less than 12 air changes per hour

with Chapter 7
CGD — Combustible gas detection system
D — No ventilation, or ventilated at less than 6 air changes per hour
FAS — Fire alarm system
FDS — Fire detection system
FE — Portable fire extinguisher

FSS — Fire suppression system (automatic sprinkler, water spray, foam,
LFS — Low flame spread material
NA — Not applicable
NC — Noncombustible material
NEC — In accordance with NFPA 70, *National Electrical Code*
NNV — Not normally ventilated
NR — No requirement

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Table 3 (continued)

		A	B	C	D	E	F	G
		Location and Function	Fire and Explosion Hazard	Ventilation	Extent of Classified Area[3]	NEC-Area Electrical Classification (All Class I, Group D)	Material of Construction for Buildings or Structures	Fire Protection Measures
8	a	ENCLOSED AERATION BASIN OR AEROBIC SUSPENDED GROWTH SYSTEMS Aerobic treatment of wastewater not preceded by primary treatment.	Possible ignition of flammable gases or floating flammable liquids	A	Entire enclosed space not routinely entered by personnel	Division 1	NC	NR
	b			B		Division 2	NC, LC, or LFS	
9		ENCLOSED AERATION BASIN OR AEROBIC SUSPENDED GROWTH SYSTEMS Aerobic treatment of wastewater preceded by primary treatment.	NA	NR	Entire enclosed space	Unclassified	NC, LC, or LFS	NR
10		TRICKLING FILTER, BIO-TOWER, AEROBIC FIXED FILM SYSTEMS Aerobic biological treatment of wastewater.	Not normally a significant hazard; however, these processes might contain materials that are combustible under certain conditions	NA		Unclassified (If unit process is not preceded by primary sedimentation, refer to primary sedimentation in Table 3 for classification.)	NR	H
11	a	ANAEROBIC TOWERS, ANAEROBIC FIXED FILM SYSTEM Anaerobic biological treatment if sealed from atmosphere.	Normally produces combustible gas as treatment process by-product	NA	Tank interior	Division 1	NC	FE and H
	b			NA	10-ft (3-m) envelope around tank	Division 2	NC, LC, or LFS	
12	a	GAS-HANDLING SYSTEMS FOR LIQUID TREATMENT PROCESSES	Combustible gas, often under pressure	A	Enclosed — entire space	Division 1	NC	FE and H
	b			B		Division 2	NC, LC, or LFS	
	c			Not enclosed, open to atmosphere	Within 10-ft (3-m) envelope around equipment			
13		OXYGEN AERATION TANKS Tanks for aerobic treatment of wastewater using high purity oxygen rather than air.	Ignition of flammable gases and floating flammable liquids in an oxygen-enriched environment	NA	Enclosed space	Division 2 (If unit process is not preceded by primary sedimentation, refer to primary sedimentation in Table 3 for classification.)	Any equipment or material within the reactor space should be safe for exposure to volatile hydrocarbons in an oxygen-enriched atmosphere	Special provision for LEL monitoring and automatic isolation of equipment and oxygen supply
14		INTERMEDIATE, SECONDARY, OR TERTIARY SEDIMENTATION TANKS Separate floating and settleable solids from wastewater at various treatment stages.		NA	NA	Unclassified (If unit process is not preceded by primary sedimentation, refer to primary sedimentation in Table 3 for classification.)	NR	H

NOTE 1: Area beyond envelope is unclassified.
NOTE 2: Where liquid turbulence is not induced by aeration or other factors, the following criteria apply: interior of the tank from the minimum operating water surface to the top of the tank wall; envelope 18 in. (0.46 m) above the top of the tank and extending 18 in. (0.46 m) beyond the exterior wall; and envelope 18 in. (0.46 m) above grade extending 10 ft (3 m) horizontally from the exterior tank walls.
NOTE 3: Open channels and open structures upstream from the unit processes are to be classified the same as the downstream process they supply.

...er spray, foam,

C — Continuously ventilated at 6 air changes per hour or in accordance with Chapter 7
CGD — Combustible gas detection system
D — No ventilation, or ventilated at less than 6 air changes per hour
FAS — Fire alarm system
FDS — Fire detection system
FE — Portable fire extinguisher

LFS — Low flame spread material
NA — Not applicable
NC — Noncombustible material
NEC — In accordance with NFPA 70, *National Electrical Code*
NNV — Not normally ventilated
NR — No requirement

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Table 3 (continued)

	A	B	C	D	E	F	G
	Location and Function	Fire and Explosion Hazard	Ventilation	Extent of Classified Area[3]	NEC-Area Electrical Classification (All Class I, Group D)	Material of Construction for Buildings or Structures	Fire Protection Measures
15	FLASH MIXER OR FLOCCULATION TANKS Tanks for mixing various treatment chemicals with wastewater.		NA	NA	Unclassified (If unit process is not preceded by primary sedimentation, refer to primary sedimentation in Table 3 for classification.)	NR	H
16	NITRIFICATION AND DENTRIFICATION TANKS Tertiary treatment of wastewater to reduce or remove nitrogen.		NA	NA	Unclassified (If unit process is not preceeded by primary sedimentation, refer to primary sedimentation in Table 3 for classification.)	NR	H
17	BREAKPOINT CHLORINATION TANKS AND CHLORINE CONTACT TANKS Application of chlorine in aqueous solution to wastewater.		NA	NA	Unclassified	NR (These unit processes use corrosive chemicals that require the use of specific materials of construction. Special consideration shall be given to these materials of construction.)	H
18	AMMONIA STRIPPING TOWERS	*(See trickling filter in Table 3.)*	NA	NA	Unclassified	NR (These unit processes use corrosive chemicals. Special consideration shall be given to these materials of construction.)	H
19	INTERMEDIATE OR FINAL PUMPING STATIONS Pump(s) at intermediate stage or end of the treatment process.		NA	NA	Unclassified	NR	H
20	GRAVITY AND PRESSURE FILTERS Filtering of treated wastewater through sand or other media.		NA	NA	Unclassified	NR	H
21	CARBON COLUMN OR TANKS Vessels containing carbon for tertiary treatment of wastewater.	Significant hazard from combustible carbon material	NA	NA	Unclassified	NR	H
22	ON-SITE OZONE GENERATION SYSTEM AND OZONE CONTACT TANKS Ozone generation and purification for disinfection of wastewater.	Similar to oxygen generation with addition of being highly corrosive *(See Table D-1.)*	NA	NA	Not covered in this document	NR	NR

NOTE 1: Area beyond envelope is unclassified.
NOTE 2: Where liquid turbulence is not induced by aeration or other factors, the following criteria apply: interior of the tank from the minimum operating water surface to the top of the tank wall; envelope 18 in. (0.46 m) above the top of the tank and extending 18 in. (0.46 m) beyond the exterior wall; and envelope 18 in. (0.46 m) above grade extending 10 ft (3 m) horizontally from the exterior tank walls.
NOTE 3: Open channels and open structures upstream from the unit processes are to be classified the same as the downstream process they supply.

A — No ventilation, or ventilated at less than 12 air changes per hour
B — Continuously ventilated at 12 air changes per hour or in accordance

CGD — Combustible gas detection system
D — No ventilation, or ventilated at less than 6 air changes per hour
FAS — Fire alarm system
FDS — Fire detection system
FE — Portable fire extinguisher

FSS — Fire suppression system (automatic sprinkler, water spray, foam, gaseous, or dry chemical)
NA — Not applicable
NC — Noncombustible material
NEC — In accordance with NFPA 70, *National Electrical Code*
NNV — Not normally ventilated
NR — No requirement

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Table 3 (continued)

		A	B	C	D	E	F	G
		Location and Function	Fire and Explosion Hazard	Ventilation	Extent of Classified Area[1]	NEC-Area Electrical Classification (All Class I, Group D)	Material of Construction for Buildings or Structures	Fire Protection Measures
23		BACKWASH WATER AND WASTE BACKWASH WATER HOLDING TANKS Tanks for temporary storage of backwash water.	NA	NA	NA	Unclassified	NR	H
24		ULTRAVIOLET DISINFECTION UNIT Disinfection of wastewater by ultraviolet radiation.		NA	NA	Unclassified	NR	H
25		EFFLUENT STRUCTURES Various structures conveying treated wastewater away from treatment processes.		NA	NA	Unclassified	NR	H
26	a	ODOR CONTROL SYSTEM AREAS Areas physically separated from processes that house systems handling flammable gases.	Leakage and ignition of flammable gases	D	Entire area if enclosed	Division 2		
	b			C	Areas within 3 ft (0.9 m) of leakage sources such as fans, dampers, flexible connections, flanges, pressurized unwelded ductwork, and odor control vessels	Division 2	NC, LC, or LFS	CGD, FDS, and FE
	c				Areas beyond 3 ft (0.9 m)	Unclassified		

NOTE 1: Area beyond envelope is unclassified.
NOTE 2: Where liquid turbulence is not induced by aeration or other factors, the following criteria apply: interior of the tank from the minimum operating water surface to the top of the tank wall; envelope 18 in. (0.46 m) above the top of the tank and extending 18 in. (0.46 m) beyond the exterior wall; and envelope 18 in. (0.46 m) above grade extending 10 ft (3 m) horizontally from the exterior tank walls.
NOTE 3: Open channels and open structures upstream from the unit processes are to be classified the same as the downstream process they supply.

A — No ventilation, or ventilated at less than 12 air changes per hour
B — Continuously ventilated at 12 air changes per hour or in accordance with Chapter 7
C — Continuously ventilated at 6 air changes per hour or in accordance with Chapter 7
CGD — Combustible gas detection system
D — No ventilation, or ventilated at less than 6 air changes per hour
FAS — Fire alarm system
FDS — Fire detection system
FE — Portable fire extinguisher
FSS — Fire suppression system (automatic sprinkler, water spray, foam, gaseous, or dry chemical)
H — Hydrant protection in accordance with 5-2.4
LC — Limited-combustible material
LFS — Low flame spread material
NA — Not applicable
NC — Noncombustible material
NEC — In accordance with NFPA 70, *National Electrical Code*
NNV — Not normally ventilated
NR — No requirement

Chapter 4 Solids Treatment Processes

4-1* General.

This chapter provides minimum criteria for protection against fire and explosion hazards associated with solids treatment processes. This chapter does not address treatment of solids from industrial waste treatment processes. Tables 4(a) and 4(b) summarize the various components associated with solids treatment processes.

4-2* Design and Construction.

The design and construction of solids treatment processes shall conform to Table 4(a) and 4(b).

Table 4(a) Solids Treatment Processes

		A	B	C	D	E	F	G
		Location and Function	Fire and Explosion Hazard	Ventilation	Extent of Classified Area	NEC-Area Electrical Classification (All Class I, Group D)	Material of Construction for Buildings or Structures	Fire Protection Measures
1		COARSE AND FINE SCREENINGS HANDLING BUILDINGS Storage, conveying, or dewatering of screenings. (No exposed flow of wastewater through this building or area.)	NA	NR	NA	Unclassified	NC, LC, or LFS	H, FE, and FAS
2		GRIT-HANDLING BUILDING Storage, conveying, and dewatering of heavy small screenings and grit. (No exposed flow of wastewater through this building or area.)	NA	NR	NA	Unclassified	NC, LC, or LFS	H, FE, and FAS
3	a	SCUM-HANDLING BUILDING OR AREA Holding, dewatering, or storage.	Possible grease or flammable liquids carryover	A	Enclosed space	Division 2	NC, LC, or LFS	H, FE, and CGD if enclosed
	b			B		Unclassified		
	c			Not enclosed, open to atmosphere	NA			
4	a	SCUM PITS	Buildup of vapors from flammable or combustible liquids	A	Enclosed—entire space	Division 1	NC	H, FE, and CGD if enclosed
	b			B		Division 2	NC, LC, or LFS	
	c			Not enclosed, open to atmosphere	Within 10 ft (3 m) envelope around equipment and open channel[1]			
5	a	SCUM-PUMPING AREAS Pumping of scum, wet side of pumping station.	Carryover of floating flammable liquids	A	Enclosed—entire space	Division 1	NC	H, FE, and CGD if enclosed
	b			B		Division 2	NC, LC, or LFS	
	c			Not enclosed, open to atmosphere	Within 10 ft (3 m) envelope around equipment and open channel[1]			
6	a	SCUM-PUMPING AREAS Pumping of scum, dry side of pumping station.	Not significant	D	Enclosed space	Division 2, or unclassified if adequate positive pressure ventilation from clean air is provided with effective safeguards against ventilation failure	NC, LC, or LFS	FE
	b			C		Unclassified		
	c			Not enclosed, open to atmosphere	NA			
7		SCUM INCINERATORS[2] Elimination of scum through burning.	Firebox explosion from possible carryover of flammable scum	NR	Incinerator area if separated from scum storage	Unclassified	NC, LC, or LFS	FSS (if indoors), H, and FE

NOTE 1: Area beyond envelope is unclassified.
NOTE 2: See NFPA 54, NFPA 82, NFPA 8501, and NFPA 8502.

A — No ventilation, or ventilated at less than 12 air changes per hour
B — Continuously ventilated at 12 air changes per hour or in accordance with Chapter 7
C — Continuously ventilated at 6 air changes per hour or in accordance with Chapter 7
FSS — Fire suppression system (automatic sprinkler, water spray, foam, gaseous, or dry chemical)
H — Hydrant protection in accordance with 5-2.4
LC — Limited-combustible material
LFS — Low flame spread material

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FDS — Fire detection system
FE — Portable fire extinguisher
NNV — Not normally ventilated
NR — No requirement

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Table 4(a) (continued)

		A	B	C	D	E	F	G
		Location and Function	Fire and Explosion Hazard	Ventilation	Extent of Classified Area	NEC-Area Electrical Classification (All Class I, Group D)	Material of Construction for Buildings or Structures	Fire Protection Measures
8	a	SLUDGE THICKENER (CLARIFIER) Sludge concentration and removal, gravity or dissolved air flotation.	Possible generation of methane from sludge; carryover of floating flammable liquids	A	Enclosed—entire space	Division 1	NC	
	b			B		Division 2	NC, LC, or LFS	H, FE, and CGD if enclosed
	c			Not enclosed, open to atmosphere	Envelope 18 in. (0.46 m) above water surface and 10 ft (3 m) horizontally from wetted walls[1]			
9	a	SLUDGE PUMPING STATION DRY WELLS Dry side of a sludge pumping station.	Buildup of methane gas or flammable vapors	D	Entire dry well when physically separated from a wet well or separate structures	Division 2, or unclassified if adequate positive pressure ventilation from clean air is provided with effective safeguards against ventilation failure	NC, LC, or LFS	H and FE
	b			C	Entire dry well when physically separated from a wet well or separate structures	Unclassified		
10	a	SLUDGE STORAGE WET WELLS, PITS, AND HOLDING TANKS Retaining of sludge.	Possible generation of methane gas in explosive concentrations; carryover of floating flammable liquids	A	Enclosed—entire space	Division 1	NC	CGD, H, and FE if tank enclosed in structure
	b			B		Division 2	NC, LC, or LFS	
	c			Not enclosed, open to atmosphere	Envelope 18 in. (0.46 m) above water surface and 10 ft (3 m) horizontally from wetted walls[1]			NR
11	a	SLUDGE BLENDING TANKS AND HOLDING WELLS Retaining of sludge with some agitation.	Possible generation of methane gas in explosive concentrations; carryover of floating flammable liquids	A	Enclosed—entire space	Division 1	NC	H, FE, and CGD if tank enclosed in structure
	b			B		Division 2	NC, LC, or LFS	
	c			Not enclosed, open to atmosphere	Envelope 18 in. (0.46 m) above water surface and 10 ft (3 m) horizontally from wetted walls[1]			NR
12		DEWATERING BUILDINGS CONTAINING CENTRIFUGES, GRAVITY BELT THICKENERS, BELT AND VACUUM FILTERS, AND FILTER PRESSES Removal of water from sludge and the conveyance of sludge or sludge cake.	NA	NR	NA	Unclassified	NC, LC, or LFS	FE, FDS, and FAS

NOTE 1: Area beyond envelope is unclassified.
NOTE 2: See NFPA 54, NFPA 82, NFPA 8501, and NFPA 8502.

A — No ventilation, or ventilated at less than 12 air changes per hour
B — Continuously ventilated at 12 air changes per hour or in accordance with Chapter 7
FSS — Fire suppression system (automatic sprinkler, water spray, foam, gaseous, or dry chemical)
H — Hydrant protection in accordance with 5-9.4

FAS — Fire alarm system
FDS — Fire detection system
FE — Portable fire extinguisher
NC — Noncombustible material
NEC — In accordance with NFPA 70, *National Electrical Code*
NNV — Not normally ventilated
NR — No requirement

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Table 4(a) (continued)

		A	B	C	D	E	F	G
		Location and Function	Fire and Explosion Hazard	Ventilation	Extent of Classified Area	NEC-Area Electrical Classification (All Class I, Group D)	Material of Construction for Buildings or Structures	Fire Protection Measures
13		INCINERATORS[5] AND INCINERATOR BUILDINGS Conveying and burning of sludge cake.	Firebox explosion	NR	NA	Unclassified	NC, LC, or LFS	FSS (if indoors), H, and FE
14		HEAT TREATMENT UNITS, LOW- OR HIGH-PRESSURE OXIDATION UNITS Closed oxidation of sludge.	None, other than in high pressure systems	NR	NA	Unclassified	NC, LC, or LFS	H and FE
15	a	ANAEROBIC DIGESTERS, BOTH FIXED ROOF AND FLOATING COVER Generation of sludge gas from digesting sludge.	Leakage of gas from cover, piping, emergency relief valves, and appurtenances	Not enclosed, open to atmosphere	Tank interior. Areas above and around the digester cover. Envelope 10 ft (3 m) above the highest point of the cover, when the cover is at its maximum elevation, and 5 ft (1.5 m) from any wall.	Division 1	NC	H and FE
	b				Envelope 15 ft (4.6 m) above the Division 1 area over the cover and 5 ft (1.5 m) beyond the Division 1 area around the tank walls.	Division 2		
	c			A	For digester tanks enclosed in a building: Tank interior. Entire area inside building.	Division 1	NC	CGD if enclosed
	d			B	For digester tanks enclosed in a building: Tank interior. Areas above and around the digester cover. Envelope 10 ft (3 m) above the highest point of the cover, when the cover is at its maximum elevation, and 5 ft (1.5 m) from any wall of the digester tank.	Division 1	NC	CGD if enclosed
	e				Remaining space in enclosed area	Division 2	NC, LC, or LFS	
16	a	ANAEROBIC DIGESTER CONTROL BUILDING Storage, handling, or burning of sludge gas.	Leaking and ignition of sludge gas	A	Entire building	Division 1	NC	CGD, H, and FE
	b			B	Enclosed areas that contain gas handling equipment	Division 2	NC, LC, or LFS	
	c			C	Physically separated from above	Unclassified		

NOTE 1: Area beyond envelope is unclassified.
NOTE 2: See NFPA 54, NFPA 82, NFPA 8501, and NFPA 8502.

A — No ventilation, or ventilated at less than 12 air changes per hour
B — Continuously ventilated at 12 air changes per hour or in accordance [illegible]
CGD — Combustible gas detection system
D — No ventilation, or ventilated at less than 6 air changes per hour
FAS — Fire alarm system
FDS — Fire detection system
FE — Portable fire extinguisher
FSS — Fire suppression system (automatic sprinkler, water spray, foam, [illegible] or dry chemical)
NA — Not applicable
NC — Noncombustible material
NEC — In accordance with NFPA 70, *National Electrical Code*
NNV — Not normally ventilated
NR — No requirement

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Table 4(a) (continued)

		A	B	C	D	E	F	G
		Location and Function	**Fire and Explosion Hazard**	**Ventilation**	**Extent of Classified Area**	**NEC-Area Electrical Classification (All Class I, Group D)**	**Material of Construction for Buildings or Structures**	**Fire Protection Measures**
17	a	DIGESTER GAS PROCESSING ROOMS Gas compression, handling, and processing.	Sludge gas ignition	A	Entire room	Division 1	NC	CGD, H, and FE
	b			B		Division 2	NC, LC, or LFS	
	c			B	Within 5 ft (1.5 m) of equipment	Division 1	NC, LC, or LFS	
18		ANAEROBIC DIGESTER GAS STORAGE Storage of sludge gas.	Gas storage piping and handling	NNV	*(See NFPA 54.)*	*(See NFPA 54.)*	NC, LC, or LFS	H, FE, and CGD
19		CHLORINE OXIDATION UNITS Chlorine reaction with sludge.	Chlorine is a very strong oxidizing agent	NR	NA	Unclassified	NR (These unit processes use corrosive chemicals that require the use of specific materials of construction. Special consideration shall be given to these materials of construction.)	H and FE
20	a	UNDERGROUND (PIPING) TUNNELS CONTAINING NATURAL OR SLUDGE GAS PIPING Transmission of gas, sludge, water, air, and steam via piping, and also might contain power cable and conduit.	Ignition of natural or sludge gases	D	Within 10 ft (3 m) of valves and appurtenances.	Division 1		
	b			D	Entire tunnel	Division 2	NC, LC, or LFS	CGD, FDS, and FE
	c			C	Areas within 10 ft (3 m) of valves, meters, gas check valves, condensate traps, and other piping appurtenances	Division 2		
	d			C	Areas beyond 10 ft (3 m)	Unclassified		
21		UNDERGROUND (PIPING) TUNNELS NOT CONTAINING NATURAL OR SLUDGE GAS PIPING Transmission of sludge, water, air, and steam piping, and also might contain power cable and conduit.	NA	NR	NA	Unclassified	NC, LC, or LFS	FDS and FE
22	a	COMPOSTING PILES Aerobic sludge reduction.	Liberation of ammonia and toxic gas (composting materials can self-ignite)	D	Enclosed area	Division 2	NC, LC, or LFS	H and FDS
	b			C		Unclassified		
23	a	IN-VESSEL COMPOSTING Aerobic sludge reduction.	Liberation of ammonia and toxic gas (composting materials can self-ignite)	As required by process	If enclosed, the interior of the reactor vessel plus a 10-ft (3-m) envelope around the reactor vessel	Division 2	NC	H and FDS
	b				Areas beyond 10 ft (3 m)	Unclassified		

NOTE 1: Area beyond envelope is unclassified.

pray, foam,

with Chapter 7

C — Continuously ventilated at 6 air changes per hour or in accordance with Chapter 7

CGD — Combustible gas detection system

D — No ventilation, or ventilated at less than 6 air changes per hour

FAS — Fire alarm system

FDS — Fire detection system

FE — Portable fire extinguisher

H — Hydrant protection in accordance with 5-2.4

LC — Limited-combustible material

LFS — Low flame spread material

NA — Not applicable

NC — Noncombustible material

NEC — In accordance with NFPA 70, *National Electrical Code*

NNV — Not normally ventilated

NR — No requirement

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Table 4(a) (continued)

		A	B	C	D	E	F	G
		Location and Function	Fire and Explosion Hazard	Ventilation	Extent of Classified Area	NEC-Area Electrical Classification (All Class I, Group D)	Material of Construction for Buildings or Structures	Fire Protection Measures
24	a	ODOR CONTROL SYSTEM AREAS Areas physically separated from processes that house systems handling flammable gases.	Leakage and ignition of flammable gases	D	Entire area if enclosed	Division 2	NC, LC, or LFS	CGD, FDS, and FE
	b			C	Areas within 3 ft (1.5 m) of leakage sources such as fans, dampers, flexible connections, flanges, pressurized unwelded ductwork, and odor control vessels	Division 2		
	c				Areas beyond 3 ft (1.5 m)	Unclassified		
25		PUMPING OF DRAINAGE FROM DIGESTED SLUDGE DEWATERING PROCESSES Pumping of centrate, filtrate, leachate, drying beds, etc.	NA	NR	NA	Unclassified	NC, LC, or LFS	H

NOTE 1: Area beyond envelope is unclassified.
NOTE 2: See NFPA 54, NFPA 82, NFPA 8501, and NFPA 8502.

A — No ventilation, or ventilated at less than 12 air changes per hour
B — Continuously ventilated at 12 air changes per hour or in accordance with Chapter 7
C — Continuously ventilated at 6 air changes per hour or in accordance with Chapter 7
CGD — Combustible gas detection system
D — No ventilation, or ventilated at less than 6 air changes per hour
FAS — Fire alarm system
FDS — Fire detection system
FE — Portable fire extinguisher
FSS — Fire suppression system (automatic sprinkler, water spray, foam, gaseous, or dry chemical)
H — Hydrant protection in accordance with 5-2.4
LC — Limited-combustible material
LFS — Low flame spread material
NA — Not applicable
NC — Noncombustible material
NEC — In accordance with NFPA 70, *National Electrical Code*
NNV — Not normally ventilated
NR — No requirement

Table 4(b) Solids Treatment Processes

	A	B	C	D	E	F	G
	Location and Function	Fire and Explosion Hazard	Ventilation	Extent of Classified Area	NEC-Area Electrical Classification (All Class II, Group G)	Material of Construction for Buildings or Structures	Fire Protection Measures
1	SLUDGE-DRYING PROCESSES[2]	Potential for ignition of dust	NR	Entire room[1]	Division 1[3]	NC Construction in accordance with NFPA 69	H, FAS, and FSS See NFPA 61 and NFPA 69

NOTE 1: Area beyond envelope is unclassified.
NOTE 2: See NFPA 54, NFPA 82, NFPA 8501, and NFPA 8502.
NOTE 3: If acceptable to the authority having jurisdiction, it shall be permitted to determine the classification using the provisions in NFPA 497B.
FAS — Fire alarm system
FSS — Fire suppression system (automatic sprinkler, water spray, foam, gaseous, or dry chemical)
H — Hydrant protection in accordance with 5-2.4
NC — Noncombustible material
NR — No requirement

Chapter 5 Fire and Explosion Prevention and Protection

5-1* Scope.

This chapter establishes minimum requirements for overall protection against fire and explosion hazards in wastewater facilities and associated collection systems. The conditions created by the existence of gases, liquids, and solids can be grouped into two categories: flammable/combustible and injurious to life. While this standard deals primarily with the flammability aspects of a particular substance, process, or area within a plant, additional requirements to protect against other safety and health hazards are contained in NFPA *101*®, *Life Safety Code*®, and NFPA 70E, *Standard for Electrical Safety Requirements for Employee Workplaces*, and shall be considered part of NFPA 820.

5-2 Fire Protection Measures.

5-2.1 General.

5-2.1.1 Collection systems, liquid stream treatment processes, and solids handling processes shall be provided with fire protection appropriate to the fire hazard as described in Tables 2 through 4(a) and (b).

5-2.1.2 In addition to the fire protection specified in Chapter 6, buildings, structures, and process elements under some conditions shall be provided with automatic extinguishing systems in accordance with Chapter 5.

5-2.2 Automatic Sprinkler Systems.

5-2.2.1 An automatic sprinkler system where required by this standard or by referenced publications shall conform to NFPA 13, *Standard for the Installation of Sprinkler Systems*, and shall be approved by the authority having jurisdiction.

Exception: In certain areas of the wastewater treatment plant, such as chemical storage, underground tunnels or structures, areas where electrical hazard is a principal concern, or where water damage would seriously impair the integrity of the treatment plant, other automatic *extinguishing systems shall be permitted.*

5-2.3 Other Automatic Extinguishing Systems.

Where required or used in place of automatic sprinkler systems, special hazard extinguishing systems and nonwater automatic extinguishing systems shall be designed, installed, and maintained in accordance with the following standards, as applicable:

(a) NFPA 11, *Standard for Low-Expansion Foam*;

(b) NFPA 11A, *Standard for Medium- and High-Expansion Foam Systems*;

(c) NFPA 11C, *Standard for Mobile Foam Apparatus*;

(d) NFPA 12, *Standard on Carbon Dioxide Extinguishing Systems*;

(e) NFPA 12A, *Standard on Halon 1301 Fire Extinguishing Systems*;

(f) NFPA 15, *Standard for Water Spray Fixed Systems for Fire Protection*;

(g) NFPA 16, *Standard on the Installation of Deluge Foam-Water Sprinkler and Foam-Water Spray Systems*;

(h) NFPA 17, *Standard for Dry Chemical Extinguishing Systems*; and

(i) NFPA 2001, *Standard on Clean Agent Fire Extinguishing Systems*.

5-2.4 Water Supplies, Standpipes, Hose Systems, and Hydrants.

5-2.4.1 Water supplies shall be capable of delivering the total demand of sprinklers, hose streams, and foam systems. In areas where there is no public water supply or where the supply is inadequate, treatment plant effluent shall be permitted for fire protection use. Where connections are made from public water supplies, it might be necessary to guard against possible contamination of the public supply. The requirements of the public health authority having jurisdiction shall be determined and followed.

5-2.4.2 Water supplies and hydrants shall be installed in accordance with the following standards, as applicable:

(a) NFPA 22, *Standard for Water Tanks for Private Fire Protection*;

(b) NFPA 24, *Standard for the Installation of Private Fire Service Mains and Their Appurtenances*; and

(c) NFPA 1231, *Standard on Water Supplies for Suburban and Rural Fire Fighting*.

5-2.4.3 Standpipes and hose systems, where provided, shall be installed and inspected in accordance with NFPA 14, *Standard for the Installation of Standpipe and Hose Systems*.

5-2.4.4 Where fire pumps are used as a separate and sole source of supply, the system shall provide sufficient capacity to meet fire water flow requirements and shall be equipped with a standby power supply. Pumps shall be automatic starting and manual shutdown. Pumps shall be installed in accordance with NFPA 20, *Standard for the Installation of Centrifugal Fire Pumps*.

5-2.5 Portable Fire Extinguishers.

Portable fire extinguishers shall be installed, located, and maintained in accordance with NFPA 10, *Standard for Portable Fire Extinguishers*.

Exception: In areas of the treatment plant not commonly occupied, such as basement and underground pipe galleries connecting buildings, the requirement for the permanent installation of portable fire extinguishers might not be appropriate. In these cases, the provision of portable fire extinguishers adequate for the hazards involved and acceptable to the authority having jurisdiction during all times the areas are occupied shall meet the intent of this standard.

5-3 Fire Detection and Alarm Systems.

5-3.1

Fire detection and alarm systems of a type appropriate to each treatment plant area shall be provided as identified in Tables 2, 3, and 4(a) and (b) or by referenced publications.

5-3.2

Fire detection and alarm systems, where required, shall be installed and maintained in accordance with the NFPA 72, *National Fire Alarm Code*.

5-4 Combustible Gas Detection.

5-4.1*

Combustible gas detectors shall be located in accordance with Tables 2, 3, and 4(a).

5-4.2*

The selection of combustible gas detector types and their placement shall be determined by a qualified person.

5-4.3

Combustible gas detectors shall be listed. The installation of combustible gas detectors shall be in accordance with their listing requirements and the manufacturer's instructions.

5-4.4

Combustible gas detection equipment located in hazardous (classified) locations, as defined in accordance with NFPA 70, *National Electrical Code*, shall be listed for use in such atmospheres. The detectors shall be set at 10 percent of the lower explosive limit in accordance with the manufacturer's calibration instructions and shall be connected to alarm signaling systems.

Exception: Alarm limits shall be permitted to be set at a higher percentage of the explosive limit where experience indicates ambient levels are too high and spurious alarms might be the result.

5-5 Ventilation Monitoring and Signaling Systems.

5-5.1

All continuous ventilation systems shall be fitted with flow detection devices connected to alarm signaling systems to indicate ventilation system failure.

5-5.2

Local and remote alarms for both ventilation system failure and combustible gas detection shall be provided for all hazardous areas classified in accordance with the following:

(a) Article 500 of NFPA 70, *National Electrical Code*;

(b) Any space pressurized in accordance with Chapters 2, 3, and 4; or

(c) Chapter 7 and NFPA 496, *Standard for Purged and Pressurized Enclosures for Electrical Equipment*.

5-5.3*

The alarms required in 5-5.2 shall be displayed in accordance with Table 5-5.3.

Table 5-5.3 Ventilation System Alarm Devices for Areas Indicated in 5-5.2

Location/Supervision	Alarm Devices and Supervision
1. Entrance(s) to such spaces[1]	Visual and audible alarm or equivalent
2. Within such spaces	Visual and audible alarm
3. Local (within treatment plant or building)	Visual and audible alarm
4. Remote (for distant supervision)[2]	Visual and audible alarm

[1]Where locations are not constantly attended, the use of a nonaudible signal is permissible if a dual light system or equivalent is used. A dual light system shall include a "go"/"no go" or green light/red light type of warning system instead of the audible alarm.

[2]In appropriate situations and where this is impractical, a telephone dialer shall be considered to meet the intent of this portion of the table.

5-5.4

Signaling systems shall be in accordance with the requirements for supervised signaling systems as set forth in NFPA 72, *National Fire Alarm Code*.

5-6 Laboratories.

Fire protection for laboratories shall be in accordance with NFPA 45, *Standard on Fire Protection for Laboratories Using Chemicals*.

5-7 Special Fire Protection Measures.

5-7.1 Fire Protection During Construction.

Fire protection measures during construction at both new and existing wastewater facilities shall be provided in accordance with NFPA 241, *Standard for Safeguarding Construction, Alteration, and Demolition Operations*, and NFPA 395, *Standard for the Storage of Flammable and Combustible Liquids at Farms and Isolated Sites*.

5-7.2 Lightning Protection.

Lightning protection shall be provided in accordance with NFPA 780, *Standard for the Installation of Lightning Protection Systems.*

5-7.3 Drainage.

5-7.3.1 Provisions shall be made in all fire areas of the plant for removal of all liquids directly to safe areas or for containment in the fire area without flooding of equipment and without endangering other areas. Caution shall be taken to avoid washing hazardous or toxic products of combustion into the drainage system.

5-7.3.2 The provisions for drainage and any associated drainage facilities shall be sized to accommodate all three of the following simultaneously:

(a) The spill of the largest single container of any flammable or combustible liquids in the area,

(b) The maximum expected number of fire hose lines [500 gal/min (31.5 L/sec) minimum] operating for a minimum of 10 min, and

(c) The maximum design discharge of fixed fire suppression systems operating for a minimum of 10 min.

Chapter 6 Materials of Construction

6-1 General.

6-1.1

This chapter provides minimum criteria for selecting materials of construction for buildings, structures, and process elements for protection against fire and explosion in wastewater treatment plants and associated collection systems. In general, materials of construction and interior coatings and finishes shall provide a maximum degree of fire resistance with the minimum amount of flame spread and smoke generation for a particular application.

6-1.2

Materials shall be selected that reduce or eliminate the effects of fire and explosion by maintaining structural integrity, controlling flame spread and smoke generation, minimizing the release of toxic products of combustion, and maintaining serviceability and operation of critical processes. The criteria for selecting materials of construction is not intended to provide sufficient protection of personnel from the risk of exposure to an asphyxiating or toxic atmosphere generated during a fire event.

Exception: In general, criteria for selecting materials of construction do not apply to nonprocess contents of the building, structure, or assembly where such contents are not a part of the building, structure, or assembly, including, but not limited to, equipment or equipment enclosures, grating, walkways, ladders, railings, weirs, process piping and appurtenances, process media, aeration devices, slide and sluice gates, pump packing and seal material, electrical conduit, hardware, liners for basins that are open to the atmosphere, or materials used in rehabilitation or for lining existing sewer pipes.

6-1.3

In areas where corrosive environments are present, including classified areas, special attention shall be given to mitigation of corrosion problems in the selection and use of materials for nonstructural assemblies, including the use of corrosion-resistant metallic or nonmetallic grating, railings, steps and stairs, conduit, and electric equipment enclosures.

6-1.4

Other local approving authorities and governing codes shall dictate more stringent material selection requirements, when appropriate.

6-2 Materials Selection.

6-2.1

Materials shall be selected based on criteria for a particular application. Selection criteria shall include:

(a) Structural requirements,

(b) Location and operating environment,

(c) Fire rating,

(d) Flame spread value,

(e) Smoke density generation factors,

(f) Products of combustion, and

(g) Corrosion resistance.

6-2.2

For the purpose of this document, materials of construction are divided into four basic categories: (a) combustible, (b) noncombustible, (c) limited-combustible, and (d) low flame spread.

6-2.3

Materials of construction being considered for unit processes located in areas with an electrical classification of Class I, Division 1 or Division 2, and Class II shall be selected based on an overall evaluation including fire risk of the material attributes, the economic impacts of replacing the unit process, and the potential environmental dangers caused by having the unit process out of service for an extended period of time due to fire or explosion.

6-3 Applications.

6-3.1* Sewers and Appurtenances.

Materials of construction for sewers and appurtenances such as maintenance holes, junction chambers, and catch basins shall be based on the results of a written materials risk assessment.

6-3.2 Pumping Facilities.

Materials selected for wastewater pumping facilities shall be in accordance with Table 2.

Exception No. 1: When conditions or applications warrant the selection of combustible materials for pumping facilities, consideration to flame spread, smoke generation, corrosion resistance, products of combustion, and the impact that a fire or explosion will have on the structural integrity, operability of the pumping facility, and the economic and environmental consequences of having the pumping facility out of service shall be included in the fire risk evaluation.

Exception No. 2: Small aboveground pumping facilities with a floor area of 100 ft^2 (9.3 m^2) or less and physically separated from the wet well and that do not present a fire hazard to other buildings or structures shall be permitted to be constructed of any appropriate materials.

6-3.3 Buildings and Structures.

6-3.3.1 General. Buildings and structures, including domes and covers, shall be constructed of materials in accordance with Tables 2, 3, and 4(a) and (b).

Exception No. 1: When conditions or applications warrant the selection of combustible materials for buildings and structures, consideration to flame spread, smoke generation, corrosion resistance, products of combustion, and the impact that a fire or explosion will have on the structural integrity, operability of the facility, and the economic and environmental consequences of having the facility out of service shall be included in the fire risk evaluation.

Exception No. 2: Small aboveground buildings and structures, including domes and covers, with a floor or surface area of 100 ft^2 (9.3 m^2) or less and physically separated from other buildings or structures and that do not present a fire hazard to other buildings or structures shall be permitted to be constructed of any appropriate materials.

Exception No. 3: Materials other than those required by Tables 2, 3, and 4(a) and (b) shall be permitted in buildings or structures that are fully sprinklered in accordance with NFPA 13, Standard for the Installation of Sprinkler Systems.

6-3.3.2 Critical Unit Processes.

6-3.3.2.1 Buildings and structures, including domes and covers, containing unit processes that are considered critical to maintaining the integrity of the treatment plant (e.g., headworks, main pumping facility, primary clarifiers, etc.), and that if out of service for even a few hours could permanently or unacceptably damage the environment or endanger public health by allowing the release of raw wastewater or sludge, shall be constructed of materials meeting the definition of noncombustible.

Exception: Except as indicated by the Exceptions to 6-3.3.1.

6-3.3.2.2 Where structural assemblies and partitions are required in these areas for fire separation in accordance with the fire risk evaluation, they shall have a minimum 3-hr fire rating.

6-3.3.2.3 Nonstructural assemblies such as ventilation ducts and piping shall be constructed of noncombustible, limited-combustible, or low flame spread materials.

6-3.3.3 Essential Unit Processes.

6-3.3.3.1 Buildings or structures, including domes and covers, containing unit processes that are considered essential to maintain the integrity of the treatment plant (e.g., secondary biological treatment, secondary clarifiers, disinfection facilities, etc.), and that if out of service for short periods of time would not permanently or unacceptably damage the environment or endanger public health but would become critical if continued for several days, shall be constructed of materials meeting the definition of noncombustible, limited-combustible, or low flame spread.

Exception: Except as indicated by the Exceptions to 6-3.3.1.

6-3.3.3.2 Where structural assemblies and partitions are used in these areas for fire separation, they shall have a minimum 2-hr fire rating.

6-3.3.3.3* Nonstructural assemblies such as ventilation ducts and piping shall be constructed of noncombustible, limited-combustible, or low flame spread materials.

6-3.3.4 Other Unit Processes.

6-3.3.4.1 Buildings and structures containing unit processes, including most sludge processing operations, that are not considered to be critical or essential to maintaining the integrity of the treatment plant, and where being out of service for long periods of time (a week or more) would not permanently or unacceptably damage the environment or endanger public health, shall be constructed of materials considered applicable by the authority having jurisdiction.

Exception: Except as indicated by the Exceptions to 6-3.3.1.

6-3.3.4.2 Where structural assemblies and partitions are used in these areas for fire separation, they shall have a minimum fire rating of 1 hr.

6-3.3.4.3 Nonstructural assemblies such as ventilation ducts and piping shall be constructed of materials meeting the definition of noncombustible, limited-combustible, or low flame spread.

6-3.3.5 Combustible Gas Generation and Combustion Processes. Buildings and structures containing unit processes that generate, process, or utilize combustible gases (e.g., anaerobic wastewater treatment processes, anaerobic digesters, compressors, storage spheres, piping, waste gas burners, gas-fired equipment including sludge incinerators, etc.) shall be constructed of materials meeting the definition of noncombustible.

Exception: Except as indicated by the Exceptions to 6-3.3.1.

6-3.3.6 Air Supply and Exhaust. Noncombustible, limited-combustible, or low flame spread materials shall be used for air supply and exhaust systems. Systems supplying or exhausting air at a rate greater than 2000 ft^3/min (56.6 m^3/min) shall include listed smoke dampers, listed fire dampers, and smoke detection and shall cause the ventilation system to shut down upon detection of smoke. Separate smoke ventilation systems shall be used where applicable.

Exception: Smoke venting shall be permitted to be integrated into normal ventilation systems using automatic or manually positioned dampers and motor speed control in accordance with NFPA 90A, Standard for the Installation of Air Conditioning and Ventilating Systems. (Also see NFPA 204M, Guide for Smoke and Heat Venting. Smoke venting also can be accomplished through the use of portable smoke ejectors.)

6-3.3.7 Miscellaneous Materials. Cellular or foamed plastic materials shall only be used in accordance with NFPA *101*, *Life Safety Code*. Roof covering shall be Class A in accordance with NFPA 256, *Standard Methods of Fire Tests of Roof Coverings*. Metal roof deck construction, where used, shall be Class I or fire classified.

Exception: Class II metal roof deck construction shall be permitted in buildings or structures that are fully sprinklered in accordance with Chapter 5.

Chapter 7 Ventilation

7-1 General.

7-1.1 Scope.

7-1.1.1 Minimum criteria for adequate ventilation for protection against fire and explosion of wastewater treatment and pumping facilities shall be in accordance with Chapters 2, 3, and 4 for the designated electrical classifications.

7-1.1.2 Ventilation criteria not addressed by Chapters 2, 3, and 4 shall meet the requirements of Table 7-3.

7-1.1.3 An “NR” designation in column C of Tables 2, 3, and 4(a) and (b) indicates that no ventilation requirements are established for the space and, therefore, Table 7-3 also has no requirements.

7-1.2

Where this standard requires certain ventilation practices, they are intended to minimize fire and explosion hazards; these ventilation standards might be insufficient to protect personnel from the toxic effects of exposure to gases present.

7-1.3

This chapter is limited to ventilation of enclosed wastewater pumping and process-related areas. It does not establish criteria applicable to spaces devoted to administrative areas, laboratories, or other ancillary spaces.

7-1.4

This chapter does not apply to at- or above-grade unroofed structures less than 2 ft (0.6 m) deep or 2 ft (0.6 m) to the normal water line or to at- or above-grade roofed structures where (a) the roof is at least 10 ft (3 m) above surrounding finished grade, and (b) the structure is open on at least three sides.

7-1.5

Because of the unpredictable nature of materials and events that can be encountered in the operation of wastewater systems, ventilation criteria established in this standard might not be adequate for protection against all hazards that might be encountered.

7-1.6

Hazardous classifications as established in Tables 2, 3, and 4(a) and (b) shall be permitted to be reduced to a lower classification (including unclassified) with positive pressurization as provided under Article 500 of NFPA 70, *National Electrical Code*. Positive pressurization shall be as described in NFPA 496, *Standard for Purged and Pressurized Enclosures for Electrical Equipment*.

7-2 Installation.

7-2.1

Ventilation systems serving spaces governed by this standard shall be designed in accordance with NFPA 90A, *Standard for the Installation of Air Conditioning and Ventilating Systems*, unless superseded by more restrictive provisions of this standard.

7-2.2

Ventilation systems serving hazardous areas classified under the provisions of Article 500 of NFPA 70, *National Electrical Code*, shall incorporate fans fabricated in accordance with AMCA Type A or B spark-resistant construction.

7-2.3

All mechanically ventilated spaces shall be served by both supply and exhaust fans.

Exception No. 1: For covered process facilities that are not routinely entered by personnel and where mechanically ventilated, the space is permitted to be ventilated by exhaust fans only. In determining the area classification, the induced supply (outside) air shall meet the ventilation *rate specified in the applicable chapter.*

Exception No. 2: Above-grade spaces with floor areas of 100 ft^2 (9.3 m^2) or less meeting the requirements of Exception No. 2 to 6-3.3.1 shall be permitted to be ventilated by a supply fan only.

7-2.4

Ventilation systems serving unclassified areas adjacent to classified areas shall maintain a differential pressure relative to ambient air pressure of 0.1 in. water column (25 Pa) under all operating conditions.

7-2.5

Ventilation systems serving classified areas shall maintain a differential pressure relative to ambient air pressure of 0.1 in. water column (25 Pa) under all operating conditions.

7-2.6

Ventilation systems for hazardous areas designed to operate intermittently or only when the space is occupied are not considered adequate for the purpose of downgrading the electrical classification of areas. (*See Chapters 2, 3, and 4.*)

7-2.7

Air shall be introduced into and exhausted from such spaces in a manner that will encourage scavenging of all portions of the spaces to avoid short-circuiting and to promote the effective removal of both heavier-and lighter-than-air gases and vapors.

7-2.8

Ventilation systems shall not transfer air between unclassified interior spaces and classified interior spaces.

7-2.9

Ventilation systems serving areas governed by this standard shall receive power from electrical equipment that receives power from a primary power source and that also has the means to accept power from alternate power sources. Minimum requirements for the means to accept the alternate source of power include connectors that are designed to connect to devices such as standby generators, portable generators, uninterruptible power supplies, etc. Automatic or manual switching to a permanent alternate source of power is also acceptable. Power failure of the primary source shall be alarmed so that appropriate emergency procedures can be started.

7-3 Ventilation Criteria.

7-3.1

Ventilation rates are based on air changes per hour and shall be calculated on the basis of the maximum aggregate volume (under normal operating conditions) of the space to be ventilated. Air changes per hour shall be based upon 100 percent outside supply air, which shall be exhausted. Ventilation rates shall conform to those listed in Table 7-3 in order to obtain the lowest area electrical classification possible in accordance with NFPA 70, *National Electrical Code*.

Table 7-3 Minimum Ventilation Rates

		Ventilation Rate, Air Changes per Hour, or Velocity as Noted		
	Description	Class I, Div. 1	Class I, Div. 2	Unclassified
1	Wet wells, screen rooms, and other enclosed spaces with wastewater exposed to the room atmosphere.	$<$ 12 air changes per hour	$\geq$ 12 air changes per hour	
2	Below-grade spaces (such as dry wells, equipment rooms, tunnels, or galleries)			
(a)	With equipment using or processing flammable gas; or	$<$ 12 air changes per hour, or $<$ 74 ft/min (22.2 m/min) velocity in tunnels or galleries	$\geq$ 12 air changes per hour, or $\geq$ 74 ft/min (22.2 m/min) velocity in tunnels or galleries	
(b)	With gas piping; or		$<$ 6 air changes per hour, or $<$ 37 ft/min (11 m/min) velocity in tunnels or galleries	$\geq$ 6 air changes per hour, or $\geq$ 37 ft/min (11 m/min) velocity in tunnels or galleries
(c)	Without gas piping.		$<$ 6 air changes per hour for dry wells	$\geq$ 6 air changes per hour for dry wells
			NR for tunnels and galleries	
3	Above-grade spaces (such as equipment rooms and galleries)			
(a)	With equipment using or processing flammable gas; or	$<$ 12 air changes per hour, or $<$ 74 ft/min (22.2 m/min) velocity for galleries	$\geq$ 12 air changes per hour, or $\geq$ 74 ft/min (22.2 m/min) velocity in galleries	
(b)	With gas piping; or		$<$ 6 air changes per hour, $<$ 37 ft/min (11 m/min) velocity in galleries	$>$ 6 air changes per hour, or $>$ 37 ft/min (11 m/min) velocity in galleries
(c)	Without gas piping.		NR for galleries	

7-3.2

Dual ventilation rates for Class I, Division 1 and Division 2 areas shall be permitted under the provisions of this document, provided (a) the low ventilation rate is not less than 50 percent of that specified in Table 7-3, (b) the low ventilation rate is in operation only if the supply air temperature is 50°F (10°C) or less, (c) the high ventilation rate is not less than that specified in Table 7-3, and (d) the high ventilation rate is in operation whenever the supply air temperature is above 50°F (10°C), whenever the ventilated space is occupied, or whenever activated by approved combustible gas detectors set to function at 10 percent of the lower explosive limit.

7-3.3*

Recirculation of up to 75 percent of the exhaust air flow rate for unclassified areas shall be permitted provided

(a) The recirculated air and outside air flow rate total is not less than 6 air changes per hour,

(b) Recirculation does not occur during occupancy, and

(c) Recirculation does not occur whenever a combustible gas detector senses a lower explosive limit of 10 percent or greater.

7-3.4

Ventilation system designs shall consider the effects of cold weather operation and the probable presence of corrosive agents.

Chapter 8 Administrative Controls

8-1 General.

This chapter establishes procedures and controls necessary for the execution of the fire prevention and fire protection activities and practices for wastewater interceptor systems, pumping stations, and treatment plants.

8-2 Management Policy and Direction.

8-2.1*

Management shall establish a policy and institute a fire prevention and protection program at each facility.

8-2.2

Combustible materials shall not be stored in areas used for the storage of toxic or reactive chemicals.

8-3* Fire Risk Evaluation.

A complete fire risk evaluation shall be performed during the initial design process.

8-4 Fire Prevention Program.

Each plant shall establish a fire prevention program. This program shall include all of the following:

(a) Fire safety information for all employees and contractors. This information shall include, as a minimum, familiarization with fire protection equipment and procedures, plant emergency alarms and procedures, and how to report a fire;

(b) Documented plant inspections including provisions for handling remedial actions to correct conditions that increase fire hazards;

(c) A description of the general housekeeping practices and the control of transient combustibles, including control of such materials stored in areas containing toxic or reactive chemicals;

(d) Control of flammable and combustible liquids and gases in accordance with NFPA 30, *Flammable and Combustible Liquids Code*, and NFPA 54, *National Fuel Gas Code*;

(e) Control of ignition sources to include smoking, grinding, welding, and cutting in accordance with NFPA 51B, *Standard for Fire Prevention in Use of Cutting and Welding Processes*;

(f) Fire prevention surveillance in accordance with NFPA 601, *Standard on Guard Service in Fire Loss Prevention*; and

(g)* Fire report, including an investigation and a statement on the corrective action to be taken.

8-5 Water-Based Fire Protection Systems.

8-5.1

These systems include fire sprinkler systems, standpipe and hose systems, water spray fixed systems, and foam-water sprinkler systems. Included are the water supplies that are part of these systems such as private fire service mains and appurtenances, fire pumps and water storage tanks, and valves controlling system flow.

8-5.2

All water-based fire protection systems shall be installed in accordance with the manufacturer's specifications and the NFPA standards referenced throughout this document, as summarized in Chapter 9.

8-5.3

All water-based fire protection systems shall be inspected, tested, and maintained in accordance with NFPA 25, *Standard for the Inspection, Testing, and Maintenance of Water-Based Fire Protection Systems*.

8-6 Other Fire Protection and Detection Systems.

8-6.1

All other fire protection and detection systems shall be installed in accordance with the manufacturer's specifications and the NFPA standards referenced throughout this document, as summarized in Chapter 9.

8-6.2*

All other fire protection and detection systems shall be periodically inspected, tested, and maintained in accordance with the NFPA standards referenced throughout this document, as summarized in Chapter 9.

8-6.3

Other fire protection system equipment not addressed by an NFPA standard as referenced in Chapter 9 (e.g., combustible gas detectors, radio communications equipment, and flame arrestors or flame checks) shall be inspected, tested, and maintained in accordance with the manufacturer's specifications.

8-7* Impairments.

8-7.1

A written procedure in accordance with NFPA 25, *Standard for the Inspection, Testing, and Maintenance of Water-Based Fire Protection Systems*, shall be established to address impairments of all water-based fire protection systems.

8-7.2

A written procedure shall be established to address impairments to other fire protection systems and plant systems that have an impact on the level of fire hazard (dust collection systems, HVAC systems, etc.). These procedures shall include the following:

(a) Identify equipment not available for service,

(b) Identify personnel to be notified (plant fire brigade chief, public fire department, etc.), and

(c) Increase fire surveillance as needed. [*See 8-4(g)*.]

8-7.3

Following repairs, tests shall be conducted on all affected systems to ensure proper operation.

8-7.4

Following restoration, all parties previously notified of the impairment shall be notified of the completion of repairs.

8-8 Fire Emergency Plan.

A written fire emergency plan shall be developed. This plan shall include the following:

(a) Response to fire alarms and fire system supervisory alarms,

(b) Notification of personnel identified in the plan,

(c) Evacuation of employees not directly involved in fire-fighting activities from the fire area,

(d) Coordination with security forces or other designated personnel to admit the public fire department and control traffic and personnel,

(e) Fire extinguishment activities, and

(f) In critical areas, operators' activities during fire emergencies. Approved breathing apparatus shall be readily available in critical areas.

8-9* Fire Brigades.

8-9.1*

If a fire brigade is provided, its organization and training shall be identified in written procedures.

8-9.2

Arrangements shall be made to permit rapid entry into the plant by the municipal fire department, police department, or other authorized personnel in the case of fire or other emergency. The Plant Emergency Organizations, where provided, shall be instructed and trained in accordance with NFPA 600, *Standard on Industrial Fire Brigades*.

8-10* Polychlorinated Biphenyls.

If polychlorinated biphenyls (PCBs) are contained within the wastewater treatment plant, the owner and the local fire officials shall prepare a contingency plan to protect the plant and the collection system from possible contamination in the event that the PCBs or combustion products are leaked or washed into the drains during a fire.

8-11 Fire and Explosion Prevention.

The principal control procedures used to minimize potential fire and explosion incidents at wastewater treatment plants shall include:

(a) Ventilation (*see Chapter 7*),

(b) Education (*see NFPA 1, Fire Prevention Code*),

(c) Risk management and property conservation programs,

(d) Procedures for permitting hot work,

(e) Selection of appropriate materials of construction (*see Chapter 6*), and

(f) Selection of appropriate equipment.

8-11.1 Control of Hazardous Source.

In-house training programs [Plant Emergency Organizations (PEO) and housekeeping or maintenance] that will provide information to understand, identify, prevent, and handle hazardous sources and situations related to potential fire, explosion, and toxicity problems shall be established for all personnel. Close liaison shall be implemented between the local fire department (including other authorized emergency personnel) and wastewater treatment plant safety personnel so that mutually approved emergency procedures (including familiarity with the plant) can be established.

8-11.2 Control of Ignition Sources.

8-11.2.1 Personnel involved shall be made familiar with the conditions for and sources of ignition of special hazards and shall be trained for the safe operation of processes. [*See 8-4(e).*]

8-11.2.2 All personnel shall be trained to report faulty equipment, worn static bonding lines, improperly stored chemicals, and other items needing correction.

8-11.3 Hot Work Permits.

Welding, cutting, and similar spark-producing operations shall not be permitted until a written permit authorizing such work has been issued. The permit shall be issued by a person in authority following his or her inspection of the area to ensure that the proper precautions have been taken and will be followed until the job is completed. (*See NFPA 51B, Standard for Fire Prevention in Use of Cutting and Welding Processes.*)

Chapter 9 Referenced Publications

9-1

The following documents or portions thereof are referenced within this standard and shall be considered part of the requirements of this document. The edition indicated for each reference is the current edition as of the date of the NFPA issuance of this document.

9-1.1 NFPA Publications.

National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.

NFPA 10, *Standard for Portable Fire Extinguishers*, 1994 edition.

NFPA 11, *Standard for Low-Expansion Foam*, 1994 edition.

NFPA 11A, *Standard for Medium- and High-Expansion Foam Systems*, 1994 edition.

NFPA 11C, *Standard for Mobile Foam Apparatus*, 1995 edition.

NFPA 12, *Standard on Carbon Dioxide Extinguishing Systems*, 1993 edition.

NFPA 12A, *Standard on Halon 1301 Fire Extinguishing Systems*, 1992 edition.

NFPA 13, *Standard for the Installation of Sprinkler Systems*, 1994 edition.

NFPA 14, *Standard for the Installation of Standpipe and Hose Systems*, 1993 edition.

NFPA 15, *Standard for Water Spray Fixed Systems for Fire Protection*, 1990 edition.

NFPA 16, *Standard on the Installation of Deluge Foam-Water Sprinkler and Foam-Water Spray Systems*, 1995 edition.

NFPA 17, *Standard for Dry Chemical Extinguishing Systems*, 1994 edition.

NFPA 20, *Standard for the Installation of Centrifugal Fire Pumps*, 1993 edition.

NFPA 22, *Standard for Water Tanks for Private Fire Protection*, 1993 edition.

NFPA 24, *Standard for the Installation of Private Fire Service Mains and Their Appurtenances*, 1995 edition.

NFPA 25, *Standard for the Inspection, Testing, and Maintenance of Water-Based Fire Protection Systems*, 1995 edition.

NFPA 30, *Flammable and Combustible Liquids Code*, 1993 edition.

NFPA 45, *Standard on Fire Protection for Laboratories Using Chemicals*, 1991 edition.

NFPA 51B, *Standard for Fire Prevention in Use of Cutting and Welding Processes*, 1994 edition.

NFPA 54, *National Fuel Gas Code*, 1992 edition.

NFPA 70, *National Electrical Code*, 1996 edition.

NFPA 70E, *Standard for Electrical Safety Requirements for Employee Workplaces*, 1995 edition.

NFPA 72, *National Fire Alarm Code*, 1993 edition.

NFPA 90A, *Standard for the Installation of Air Conditioning and Ventilating Systems*, 1993 edition.

NFPA *101*, *Life Safety Code*, 1994 edition.

NFPA 241, *Standard for Safeguarding Construction, Alteration, and Demolition Operations*, 1993 edition.

NFPA 251, *Standard Methods of Tests of Fire Endurance of Building Construction and Materials*, 1995 edition.

NFPA 255, *Standard Method of Test of Surface Burning Characteristics of Building Materials*, 1990 edition.

NFPA 256, *Standard Methods of Fire Tests of Roof Coverings*, 1993 edition.

NFPA 395, *Standard for the Storage of Flammable and Combustible Liquids at Farms and Isolated Sites*, 1993 edition.

NFPA 496, *Standard for Purged and Pressurized Enclosures for Electrical Equipment*, 1993 edition.

NFPA 600, *Standard on Industrial Fire Brigades*, 1992 edition.

NFPA 601, *Standard on Guard Service in Fire Loss Prevention*, 1992 edition.

NFPA 780, *Standard for the Installation of Lightning Protection Systems*, 1995 edition.

NFPA 1231, *Standard on Water Supplies for Suburban and Rural Fire Fighting*, 1993 edition.

NFPA 2001, *Standard on Clean Agent Fire Extinguishing Systems*, 1994 edition.

9-1.2 Other Publications.

9-1.2.1 ASTM Publications. American Society for Testing and Materials, 1916 Race Street, Philadelphia PA 19103.

ASTM E 136, *Standard Test Method for Behavior of Materials in a Vertical Tube Furnace at 750 Degrees C*, 1994.

ASTM E 814, *Standard Test Method for Fire Tests of Through-Penetration Fire Stops*, 1988 (Rev. B-94).

Appendix A Explanatory Material

This Appendix is not a part of the requirements of this NFPA document but is included for informational purposes only.

A-1-1.1.1 Consult other NFPA standards for additional requirements relating to wastewater treatment and collection facilities.

A-1-3.1

In existing facilities, it is not always practical to strictly apply the provisions of this standard. Physical limitations might necessitate disproportionate effort or expense with little increase in fire protection. In such cases, the authority having jurisdiction should be satisfied that reasonable fire protection is ensured.

In existing facilities, it is intended that any condition that represents a serious threat to fire protection be mitigated by application of appropriate safeguards. It is not intended to require modification for conditions that do not represent a significant threat to fire protection, even though such conditions are not literally in conformance with these fire protection requirements.

A-1-3.3

For additional information see NFPA 497A, *Recommended Practice for Classification of Class I Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas*, and NFPA 497B, *Recommended Practice for the Classification of Class II Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas*. While some of this information is not applicable to wastewater treatment facilities, both documents provide useful information.

A-1-5 Approved.

The National Fire Protection Association does not approve, inspect, or certify any installations, procedures, equipment, or materials; nor does it approve or evaluate testing laboratories. In determining the acceptability of installations, procedures, equipment, or materials, the authority having jurisdiction may base acceptance on compliance with NFPA or other appropriate standards. In the absence of such standards, said authority may require evidence of proper installation, procedure, or use. The authority having jurisdiction may also refer to the listings or labeling practices of an organization concerned with product evaluations that is in a position to determine compliance with appropriate standards for the current production of listed items.

A-1-5 Authority Having Jurisdiction.

The phrase “authority having jurisdiction” is used in NFPA documents in a broad manner, since jurisdictions and approval agencies vary, as do their responsibilities. Where public safety is primary, the authority having jurisdiction may be a federal, state, local, or other regional department or individual such as a fire chief; fire marshal; chief of a fire prevention bureau, labor department, or health department; building official; electrical inspector; or others having statutory authority. For insurance purposes, an insurance inspection department, rating bureau, or other insurance company representative may be the authority having jurisdiction. In many circumstances, the property owner or his or her designated agent assumes the role of the authority having jurisdiction; at government installations, the commanding officer or departmental official may be the authority having jurisdiction.

A-1-5 Listed.

The means for identifying listed equipment may vary for each organization concerned with product evaluation, some of which do not recognize equipment as listed unless it is also labeled. The authority having jurisdiction should utilize the system employed by the listing organization to identify a listed product.

A-2-1

Additional information on sources of hazards, sources of ignition, and mitigation measures associated with collection and transmission of municipal wastewater is contained in Appendix D.

A-2-2

See Figures A-2-2(a) through (g), which provide examples for Table 2.

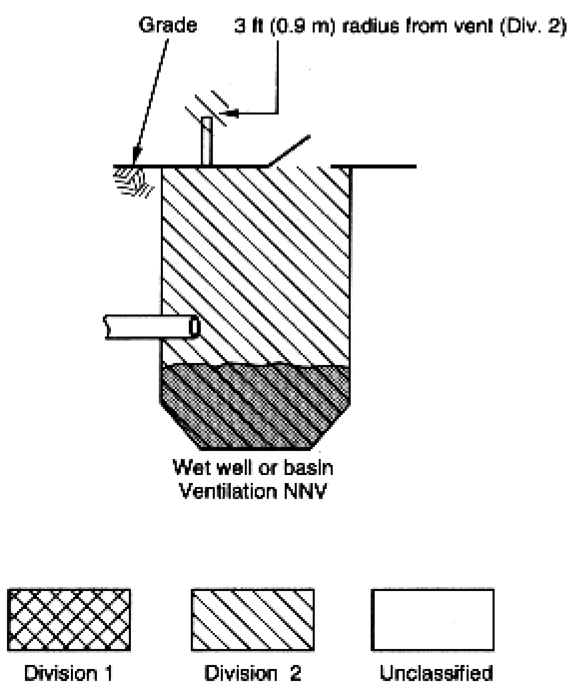


Figure A-2-2(a) Wet well or basin serving a storm sewer. Illustration of Table 2, row 4.

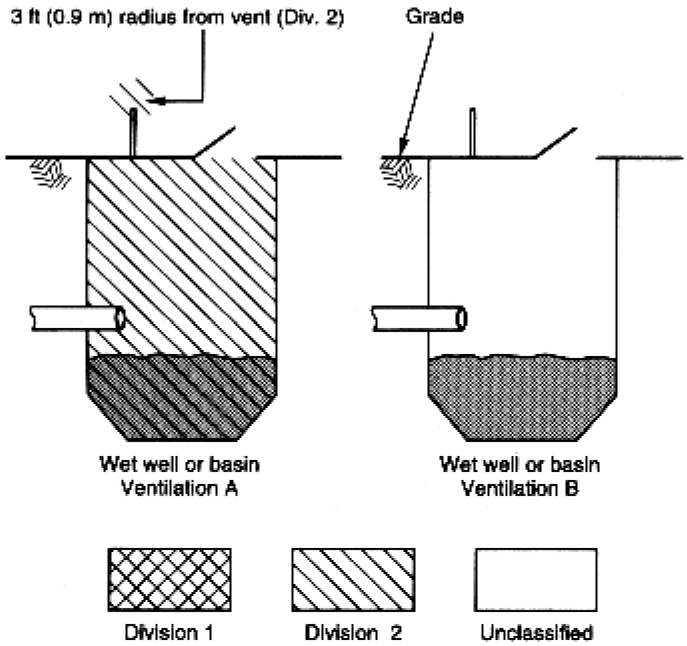


Figure A-2-2(b) Wet well or basin serving a residential sewer. Illustration of Table 2, row 11.

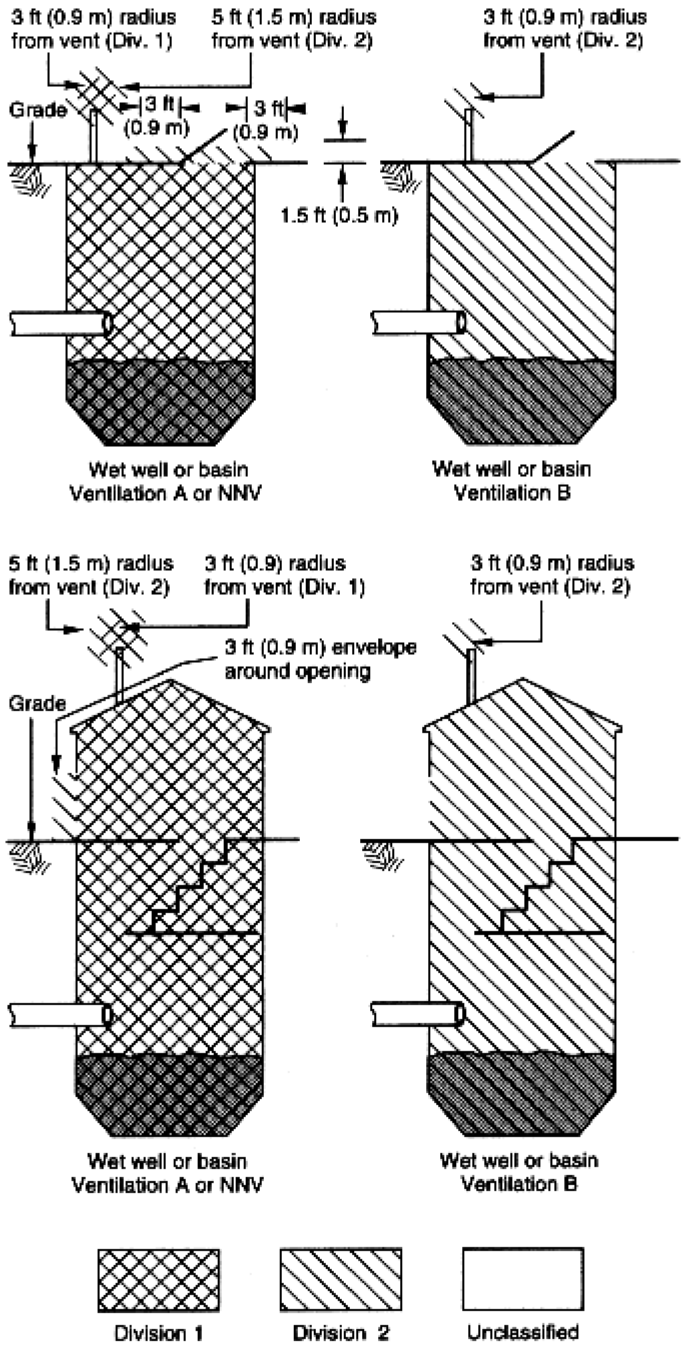


Figure A-2-2(c) Wet well or basin serving separate or combined sanitary sewer. Illustration of Table 2, rows 16 and 34.

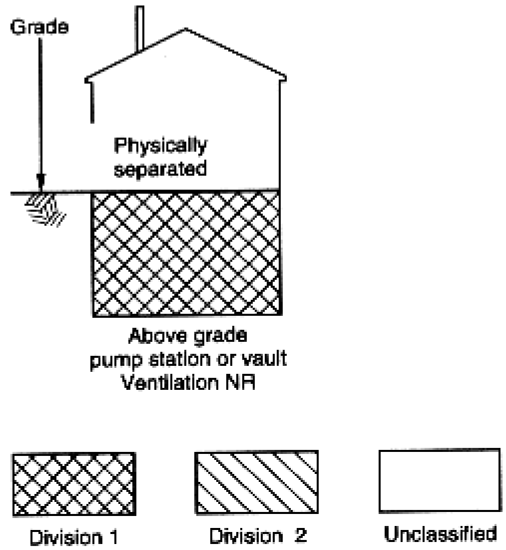


Figure A-2-2(d) Above-grade equipment housing or vault physically separated from the wet well or basin. Illustration of Table 2, rows 18 and 30.

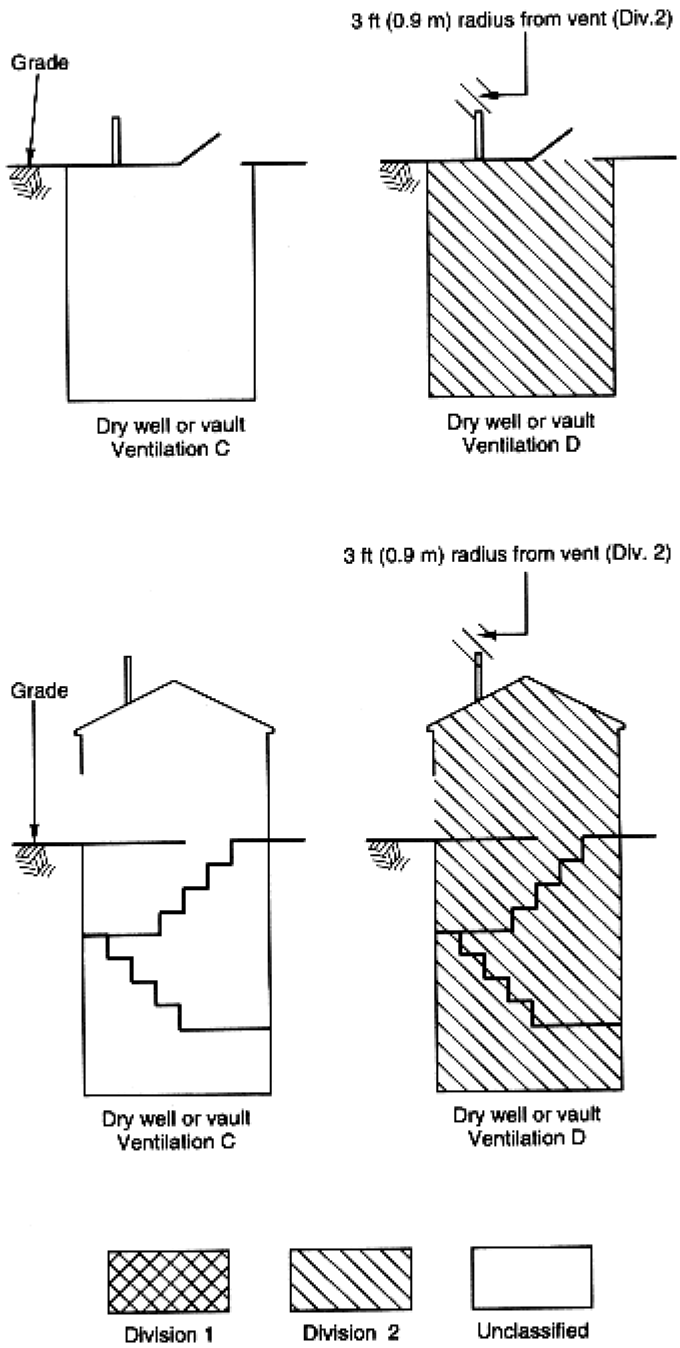


Figure A-2-2(e) Below- or partially below-grade equipment housing or vault physically separated from the wet well or basin. Illustration of Table 2, rows 5, 12, 17, 31, and 36.

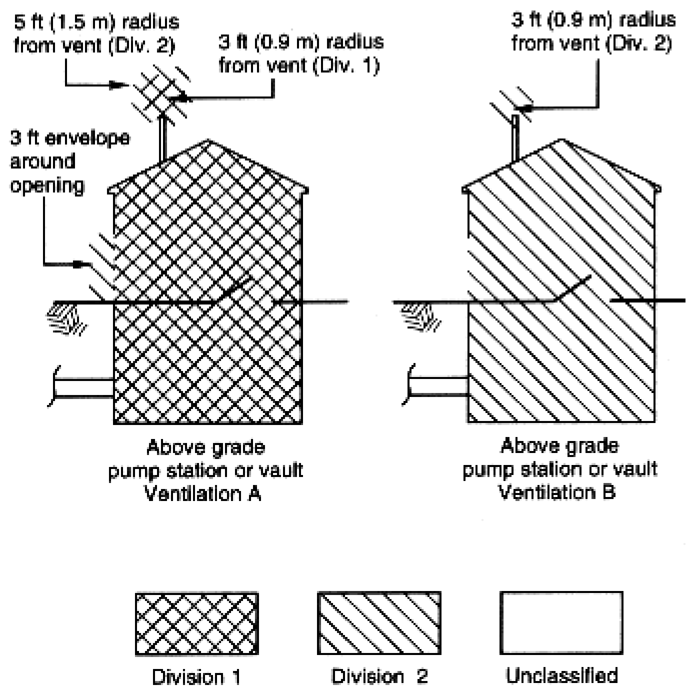


Figure A-2-2(f) Above-grade equipment housing or vault not physically separated from the wet well or basin. Illustration of Table 2, row 19.

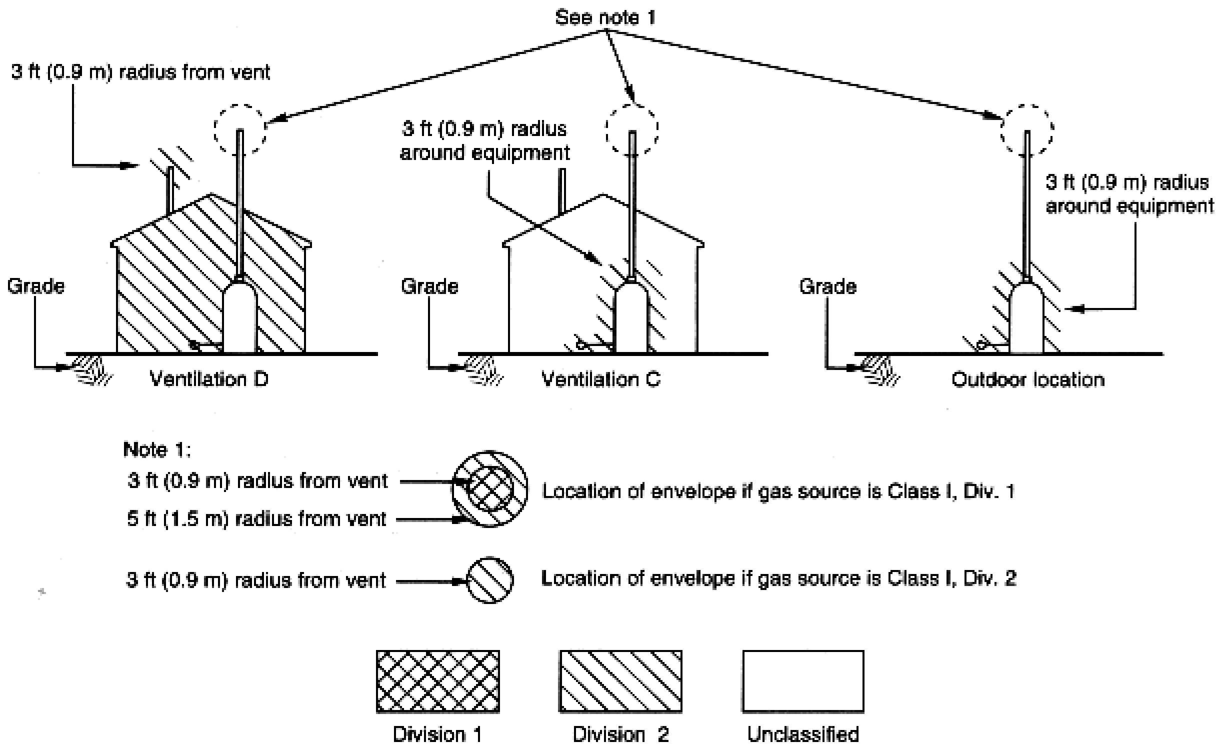


Figure A-2-2(g) Odor control system location physically separated from wet well. Illustration of Table 2, row 20.

A-3-1

Additional information on sources of ignition, sources of hazards, and mitigation measures associated with liquid stream treatment processes is contained in Appendix D.

A-3-2

See Figure A-3-2, which provides an example for Table 3.

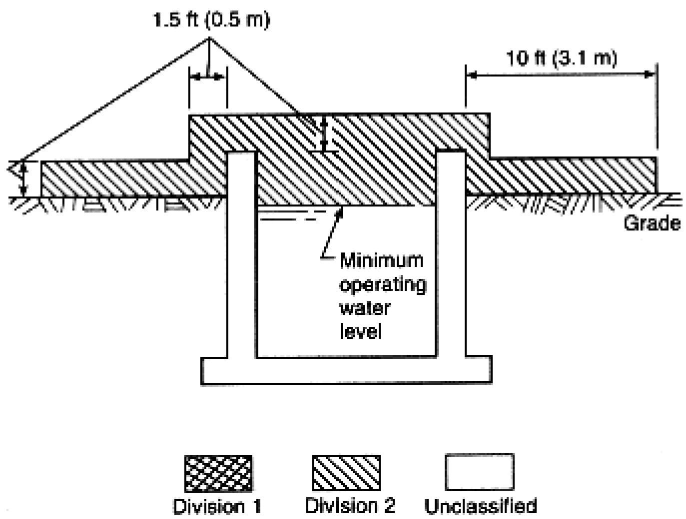


Figure A-3-2 Primary sedimentation tank. Illustration of Table 3, row 6.

A-4-1

Additional information on sources of hazards, sources of ignition, and mitigation measures associated with solids treatment processes is contained in Appendix D.

A-4-2

See Figures A-4-2(a) through A-4-2(g), which provide examples for Table 4(a).

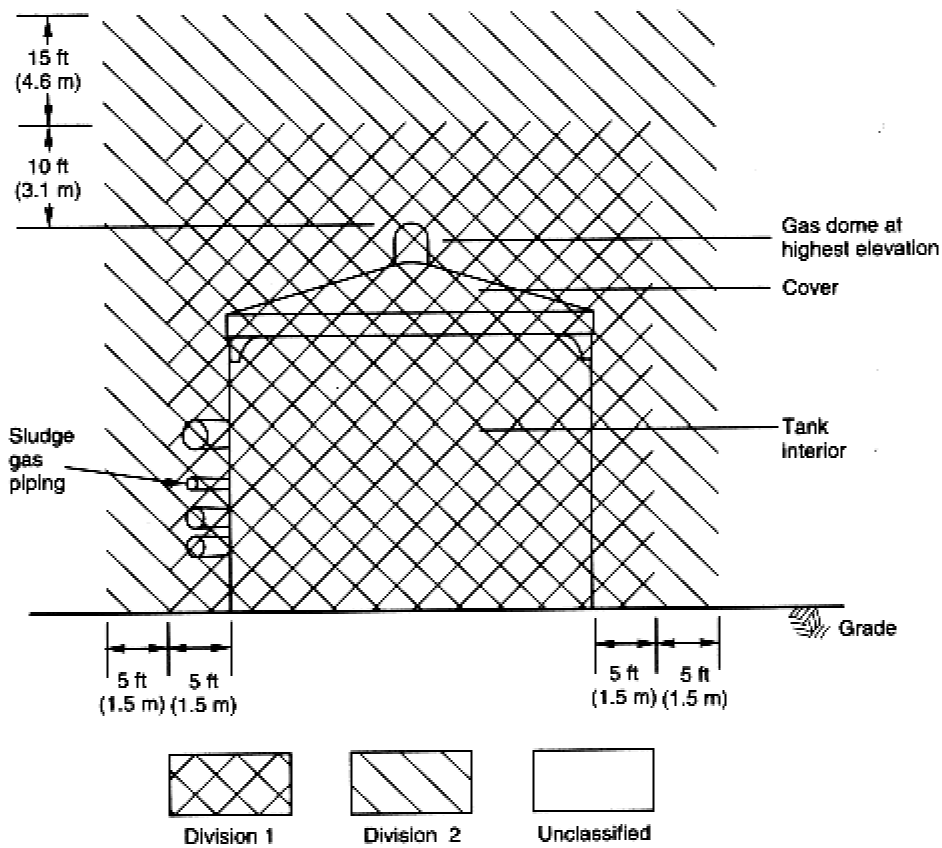


Figure A-4-2(a) Anaerobic digester with fixed or floating cover above grade not enclosed in a building. Illustration of Table 4(a), rows 15a and b.

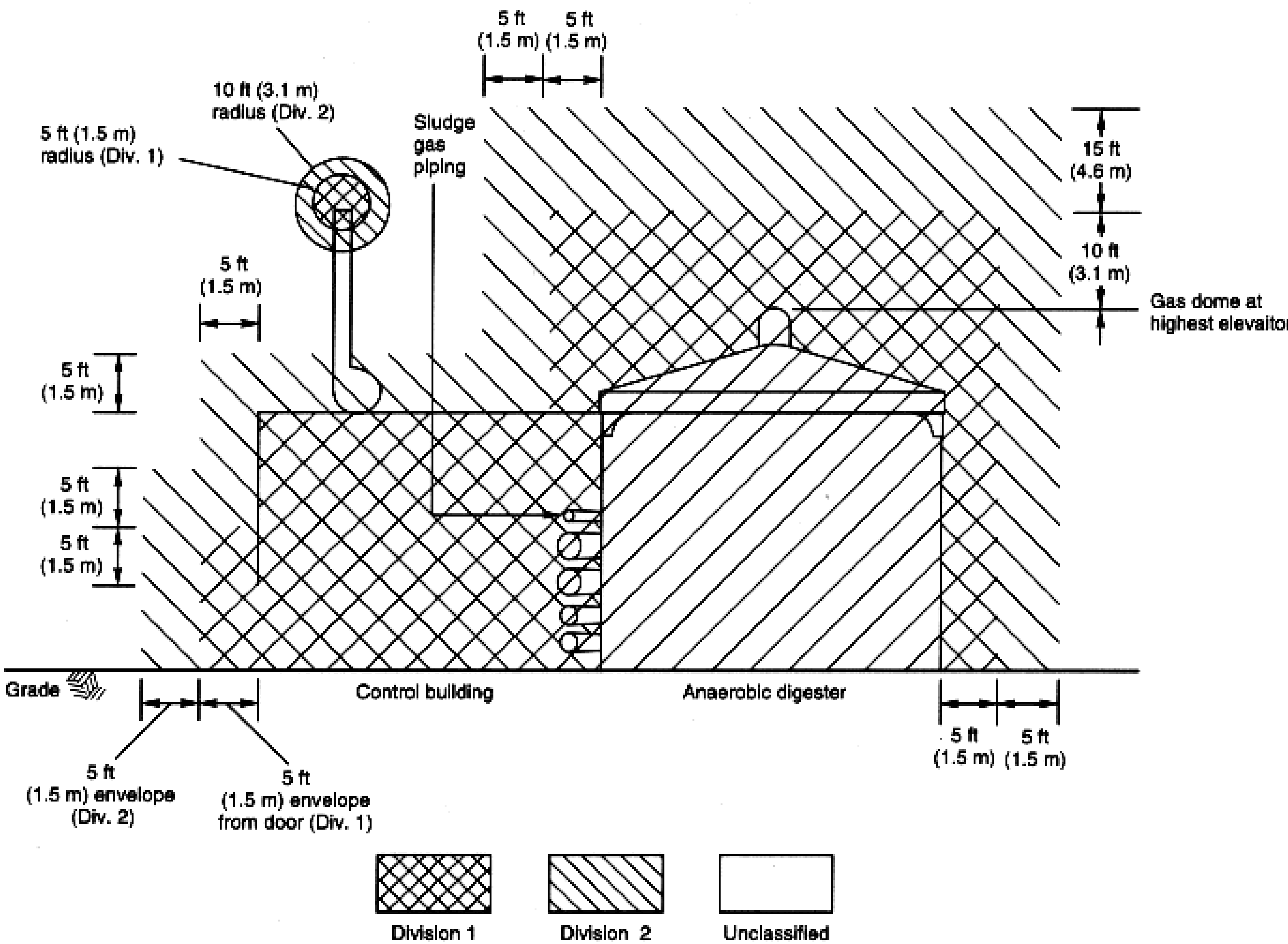


Figure A-4-2(b) Anaerobic digester control building containing sludge gas piping and with ventilation A. Illustration of Table 4(a), row 16a.

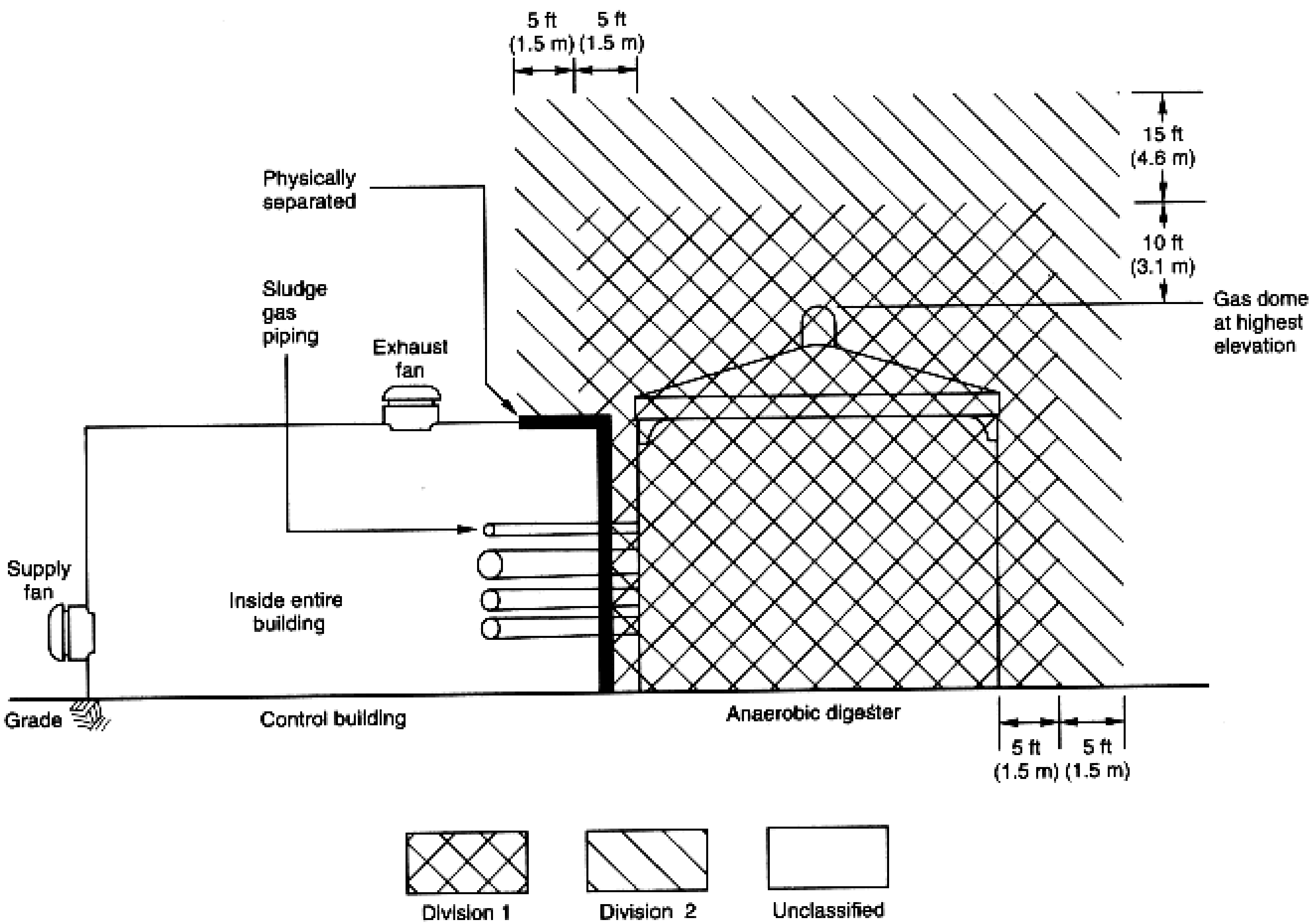


Figure A-4-2(c) Anaerobic digester control building containing sludge gas piping and with ventilation C. Illustration of Table 4(a), row 16c.

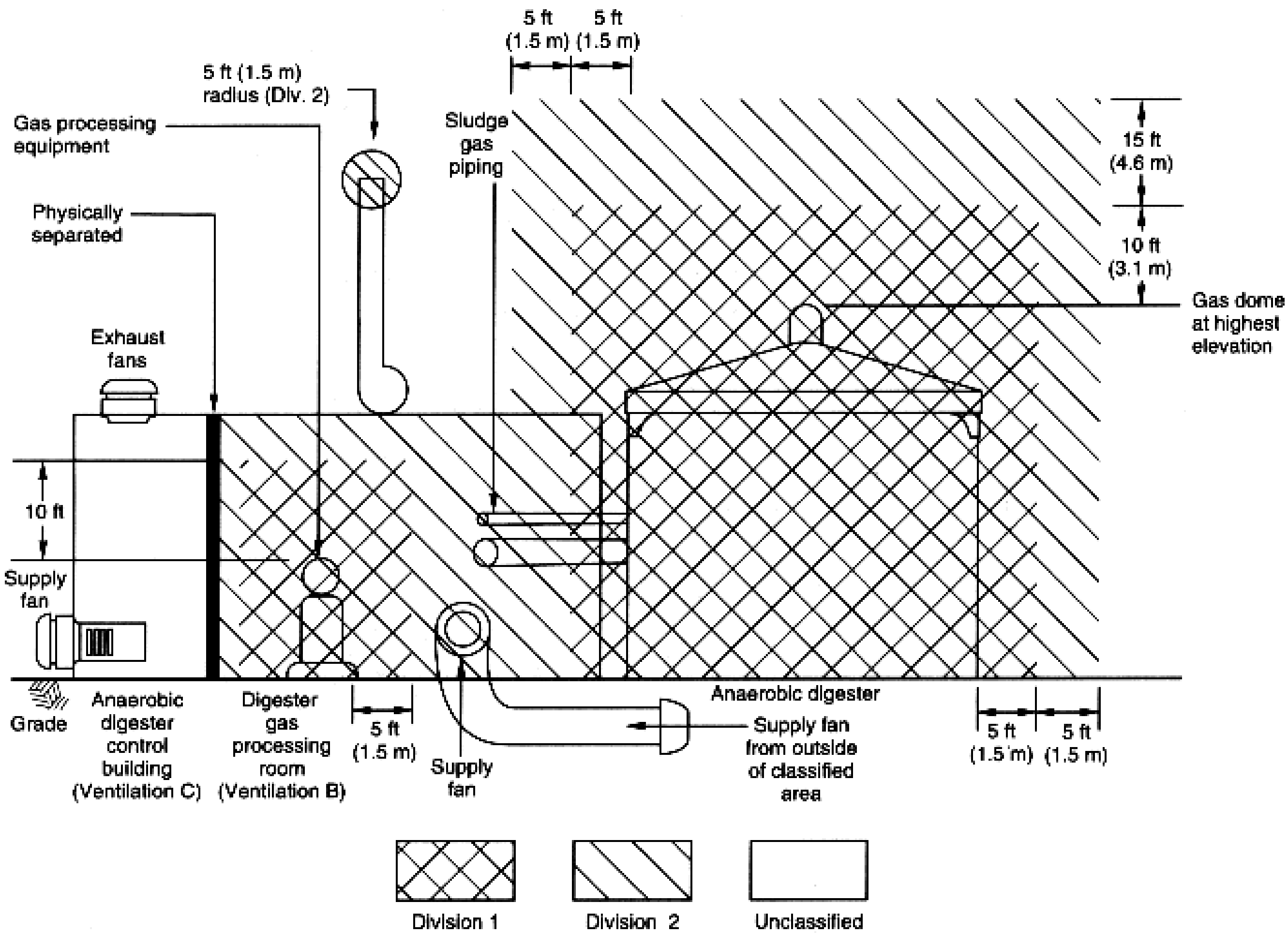


Figure A-4-2(d) Anaerobic digester control building containing sludge gas processing equipment physically separated and with ventilation B for the processing room, and ventilation C for the control building. Illustration of Table 4(a), rows 16c and 17b.

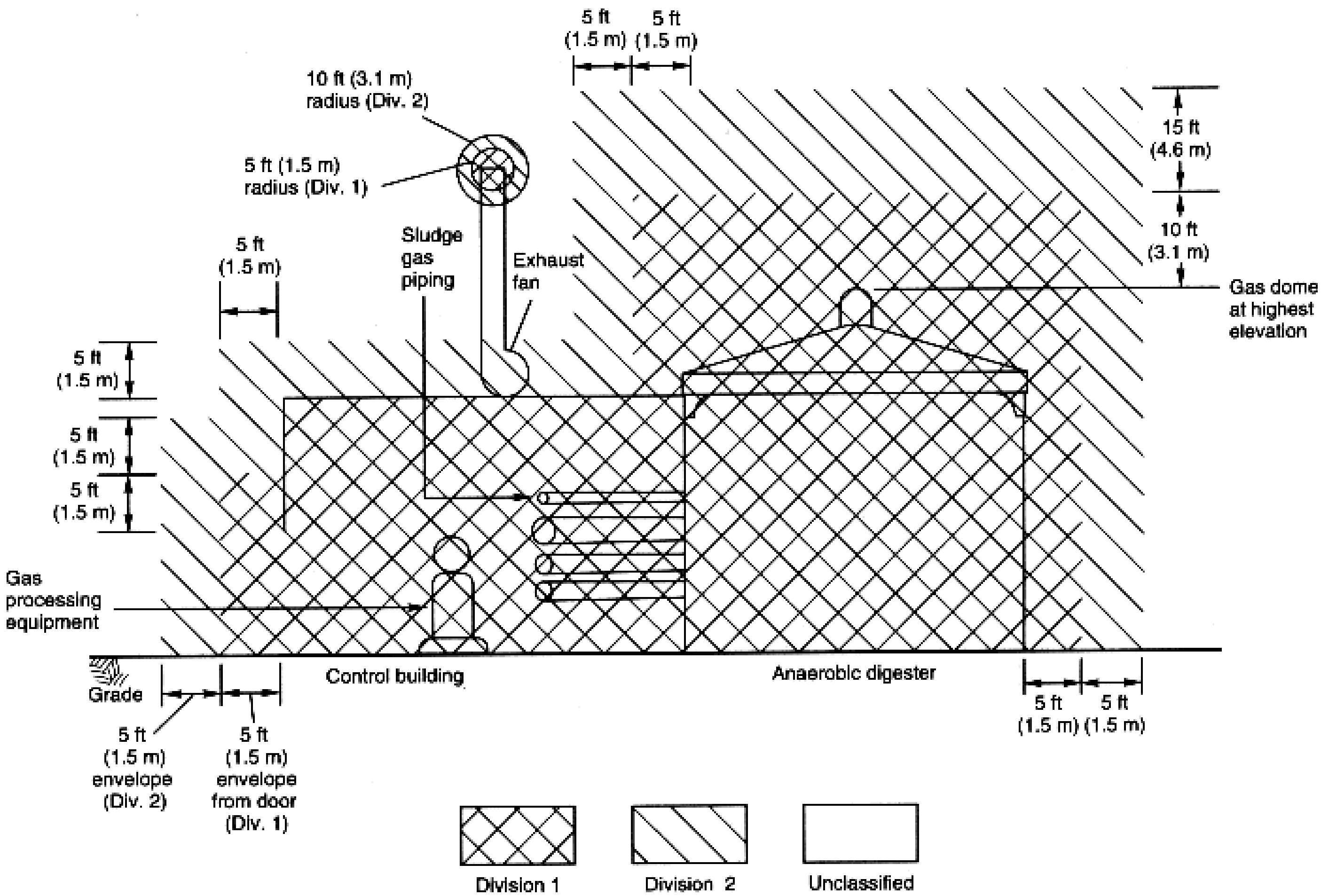


Figure A-4-2(e) Anaerobic digester control building containing sludge gas processing equipment not physically separated and with ventilation A. Illustration of Table 4(a), row 16.

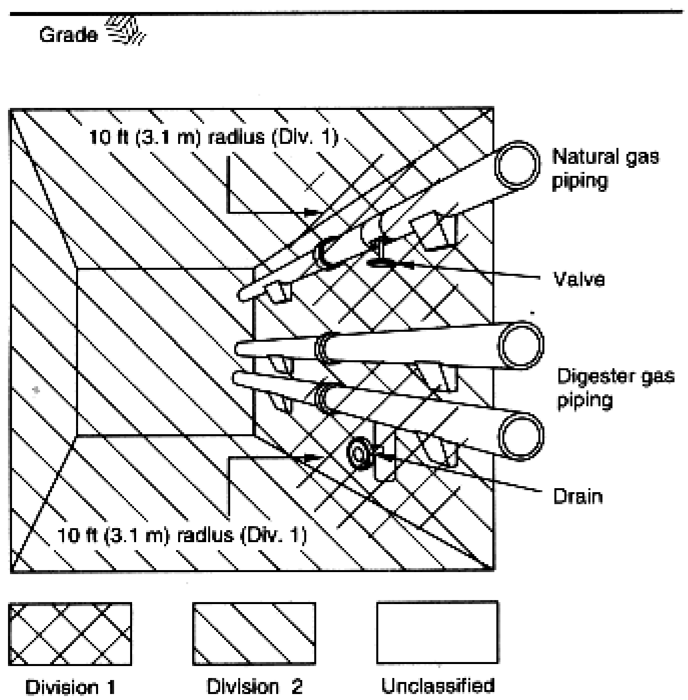


Figure A-4-2(f) Underground tunnel containing natural gas or sludge gas piping with ventilation D. Illustration of Table 4(a), rows 20a and 20b.

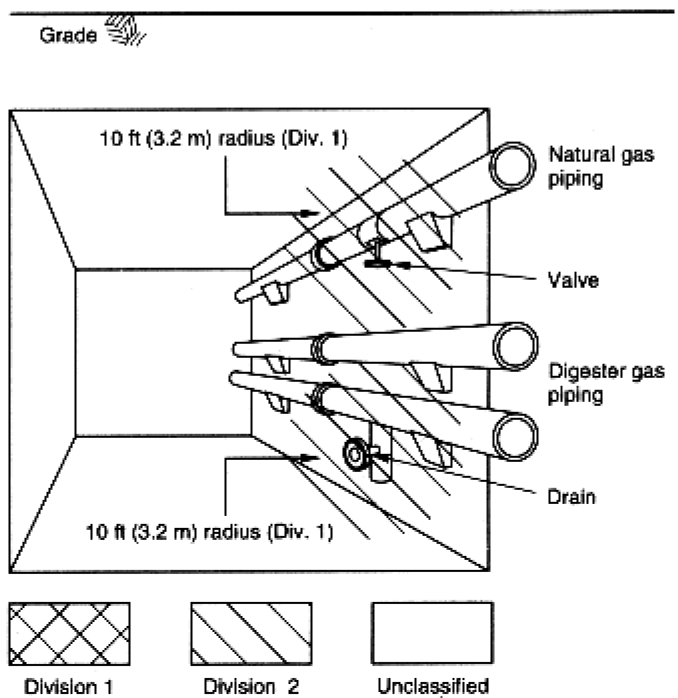


Figure A-4-2(g) Underground tunnel containing natural gas or sludge gas piping with ventilation C. Illustration of Table 4(a), rows 20c and 20d.

A-5-1

Additional information is contained in Appendix D.

A-5-4.1

For further information, refer to NFPA 328, *Recommended Practice for the Control of Flammable and Combustible Liquids and Gases in Manholes, Sewers, and Similar Underground Structures*.

A-5-4.2

Other types of detectors, such as heat and smoke detectors, have standards recommending spacing usually based on a certain area per detector. There are no known recognized standards or guidelines for the locating or spacing of combustible gas detectors.

Whether natural or mechanical, air movement is a very important consideration in installing combustible gas detectors. This aspect should be carefully investigated, including the effect of doors, windows, vents, and other openings. It might be necessary to conduct a ventilation study that could involve a nontoxic smoke movement analysis.

Dispersion characteristics can also affect detector placement. Vapors and gases will disperse inversely proportional to their specific density in a quiescent environment. Vapors and gases with densities less than that of air will diffuse quickly at first until the vapor or gas becomes diluted. Heavier-than-air vapors and gases will tend to settle at a low area and not diffuse into the atmosphere unless dispersed by ventilation or temperature currents. Vapors with densities close to that of air will exhibit little mixing effect and will be transported largely by air currents.

There are various types of sensing devices. It is important to select the proper sensing device for each application and for the environment in which it will be placed. Most organic and inorganic compounds can be safely monitored with a catalytic-combustion-type sensor. However, organic and metallic solvents containing lead, silicones, plasticizers, or halogens can poison the catalytic element.

A-5-5.3

In all cases, standard "Danger" signs identifying the purpose of the lights and audible alarms and warning against entry when there is an alarm condition should be posted as near as practical to the warning devices.

A-6-3.1

See Appendix C of this document and NFPA 328, *Recommended Practice for the Control of Flammable and Combustible Liquids and Gases in Manholes, Sewers, and Similar Underground Structures.*

A-6-3.3.3.3 Plastic or fiberglass-reinforced plastic products are often used as materials of construction in unit processes such as rotating biological contactors (RBC), bio-towers, trickling filters, inclined plate (tube) settlers, ventilation ducts, and other equipment that might be subject to corrosion. Under normal operating conditions, these plastic or fiberglass-reinforced plastic materials might be submerged; however, during maintenance or repair they can become exposed. During maintenance and repair operation, extreme care should be taken with open flame such as cutting torches, as these exposed plastic or fiberglass-reinforced plastic materials might present a considerable fuel load if ignited.

A-7-3.3

Ventilation rates and procedures established by this standard might not be sufficient to protect personnel from exposure to toxic gases that might be present in enclosed spaces.

A-8-2.1

Proper preventive maintenance of operating and fire protection equipment, as well as operator training, are important aspects of a viable fire prevention program.

A-8-3

A fire risk evaluation should result in recommendations to integrate the fire prevention and fire protection required in this document into the plant- specific considerations regarding design, layout, and anticipated operating requirements. The evaluation should result in a list of recommended fire prevention features to be provided based on acceptable means for separation or control of common and special hazards, the control or elimination of ignition sources, and the suppression of fires.

This evaluation should focus on materials of construction in ventilation systems and in processes that normally operate in a wet condition (examples: plastic media trickling filters, bio-towers, and rotating biological contactors). These systems and process units can represent a considerable fuel load if ignition occurs during operation. Maintenance, fire spread, and smoke production should be considered in the selection of materials.

Consideration should also be given to locating process areas (examples: screen room, areas containing gas management equipment, etc.) that represent a significant explosion hazard remote from other process areas to reduce the risk of consequent damage should an explosion occur.

A-8-4(g) (*See Sample Fire Report*.)

Sample Fire Report

Name of company: ____________________

Date of fire: ________ Time of fire: ________ Operating facility: ________

Under construction: ____________________

Plant or location where fire occurred: ____________________

Description of facility, fire area, or equipment (include nameplate rating) involved: ________

Cause of fire, such as probable ignition source, initial contributing fuel, equipment failure causing ignition, etc.: ________

Description of fire and events and conditions preceding, during, and after the fire: ________

Types and approximate quantities of portable extinguishing equipment used: ________

Was fire extinguished with portable equipment only? ________ Public fire department called? ________

Employee fire brigade at this location? ________ Qualified for incipient fires? ________

For interior structural fires? ________

Was fixed fire extinguishing equipment installed? ________

Type of fixed extinguishing system: ________

Automatic operation: ________ , manually actuated: ________ , or both: ________

Specific type of detection devices: ________

Did fixed extinguishing system control fire? ________ , extinguish fire ________ , both control and extinguish fire? ________

Did detection devices and extinguishing system function properly? ________

If not, why not? ________

Estimated direct damage due to fire: $ ________, or between $ ________ and $ ________

Estimated additional (consequential) loss: $ ________. Nature of additional loss: ________

Estimated time to complete repairs/replacement of damaged equipment/structure: ________

Number of persons injured: ________ Number of fatalities: ________

What corrective or preventive suggestions would you offer to other utilities who might have similar equipment, structures, or extinguishing systems? ________

A-8-6.2 Maintenance.

Once a detection system is installed, a preventive maintenance program is essential. A detection system is only as good as the care and maintenance it receives. This is especially true in harsh environments. When installing instruments, ease of calibration and maintenance should be considered. Periodic calibration, checks, and adjustments are necessary for detection to remain accurate. If instruments are inaccessible, it is more likely that maintenance procedures will not be followed. Detectors should be located so as not to be exposed to physical damage from normal activities in the area.

Consideration should be given to the scope and limitations of the listing for combustible gas detectors. For example, Underwriters Laboratories Inc., in its *Hazardous Location Equipment Directory*, offers some guidance in maintaining and using combustible gas detectors. The following is extracted from that directory's product category guide for listed gas detectors (JTPX):

Gas or vapor detectors should be calibrated and inspected by the operator in compliance with the manufacturer's instructions, as performance of the instruments will depend on proper maintenance. The instruments should be calibrated with known gas- or vapor-air mixtures at intervals and particularly after replaceable sensors incorporated in the detecting unit are replaced. Certain gases or vapors can adversely affect (poison) the sensors and limit the use of the instruments. Sampling atmospheres containing gases or vapors for which they have not been previously calibrated should, therefore, be avoided.

A-8-7

Impairments to fire protection systems should be as short in duration as practical. If the impairment is planned, all necessary parts and manpower should be assembled prior to removing the protection system from service. When an impairment is not planned, the repair work should be expedited until the repairs are completed.

A-8-9 Fire Brigades.

The size of the plant and its staff, the complexity of fire-fighting problems, and the availability of a public fire department should determine the requirements for a fire brigade. The organization of a fire brigade is encouraged for wastewater treatment facilities located in remote areas.

If a fire brigade is provided, its organization and training should be identified in written procedures. Recommendations contained in NFPA 600, *Standard on Industrial Fire Brigades*, and OSHA 29 CFR, 1910.156, should be consulted for additional information.

The following items discuss special fire-fighting conditions unique to wastewater facilities. This information might be useful in fire brigade training and fire preplanning.

(a) Cable tray fires should be handled like any fire involving energized electrical equipment. It might not be practical or desirable to de-energize the cables involved in the fire. Water is the most effective extinguishing agent for cable insulation fires, but it should be applied with an electrically safe nozzle. Some cable insulations [polyvinyl chloride (PVC), neoprene, or Hypalon™] can produce dense smoke in a very short time. In addition, PVC liberates hydrogen chloride (HCl) gas. Self-contained breathing apparatus should be used by personnel attempting to extinguish cable tray fires.

(b) Some sludge drying and composting processes (especially solvent extraction drying, sludge drying kilns, and in-vessel composting systems) might produce a product that might be subject to spontaneous combustion. Generally, water will be the most effective fire-fighting agent in these areas. However, fires might be deep-seated in stockpiled products, which might have to be dispersed with front-end loaders or similar equipment to fully extinguish smoldering and burning material.

(c) Some chlorinated hydrocarbon products commonly used as foam suppressants or flocculation agents in wastewater treatment might cause spontaneous combustion when in contact with powdered disinfectants. These chemicals should be stored separately, and care should be exercised in their use.

(d) Plastic or fiberglass-reinforced plastic materials used in process units or ventilation systems might represent a considerable fuel load if ignited during operation or maintenance and might necessitate special response techniques.

A-8-9.1

NFPA 600, *Standard on Industrial Fire Brigades*, and OSHA 29 CFR 1910.156 should be consulted.

A-8-10

Federal regulations (40 CFR, 761.30) specify that the local fire department should be notified of the location of all PCB-filled transformers and other electrical equipment.

Appendix B Wastewater Treatment Processes

This Appendix is not a part of the requirements of this NFPA document but is included for informational purposes only.

B-1 General.

B-1.1 Wastewater.

Wastewater is principally the spent water supply of the community. It is used to flush and transport human wastes and the liquid wastes of commerce, industry, and institutions. Ground water, surface water, and storm water might also be present. The primary purposes of wastewater treatment are to protect the health and well-being of the community and the quality of the receiving waterway. The extent or completeness of wastewater treatment to accomplish these purposes is governed by legislation and regulations and will vary from jurisdiction to jurisdiction.

B-1.2 Elements of Wastewater Treatment.

The principal elements of wastewater treatment are:

(a) Preliminary treatment,

(b) Primary treatment,

(c) Secondary treatment,

(d) Tertiary treatment,

(e) Disinfection, and

(f) Sludge treatment.

A typical schematic flow and process diagram for a wastewater treatment plant is shown in Figure B-1.

B-2 Preliminary Treatment.

Preliminary treatment comprises the conditioning of wastewater as it enters the wastewater treatment plant. Preliminary treatment removes materials that might be harmful to or might adversely affect the operation of the treatment plant. Such material might include lumber, cardboard, rags, stones, sand, plastic, grease, and scum. Methods and equipment used to remove these materials include bar racks, bar screens, and gravity or aerated grit chambers.

B-3 Primary Treatment.

Primary treatment is first-stage sedimentation, in which settleable, suspended, and floating material is removed from the wastewater following preliminary treatment. Well-operated primary treatment facilities can remove as much as 60 percent of the influent suspended solids and 30 percent of the influent biochemical oxygen demand. However, primary treatment does not remove colloidal or dissolved solids.

B-4 Secondary Treatment.

Secondary treatment is intended to reduce the concentrations of the remaining suspended solids and the dissolved and colloidal organic matter in the wastewater. Such material is not removed to any significant degree in primary treatment. A wastewater treatment plant having secondary treatment following primary treatment commonly can achieve removal of a total of 90 percent of the influent suspended solids and biochemical oxygen demand of the raw wastewater. Secondary treatment processes can be either biological or physical-chemical.

B-4.1 Biological Treatment.

Most municipal secondary treatment processes are biological. These processes can be classified as fixed film or suspended growth. In each process, a mixed population of microorganisms is established in the presence of oxygen. These microorganisms metabolize the dissolved organic matter in the wastewater and form a biological mass. The effluent from fixed film or suspended growth processes contains suspensions of biological solids. These solids are removed from the treated wastewater in a secondary sedimentation tank.

B-4.2 Physical-Chemical Treatment.

Physical-chemical treatment includes one or more physical-chemical unit processes to treat primary effluent. Such processes might include chemical coagulation, precipitation, and filtration to remove suspended matter and activated carbon adsorption to remove soluble organics.

B-5 Tertiary Treatment.

Tertiary treatment is used as necessary to reduce the concentration of inorganic and organic constituents below the concentrations achievable through secondary treatment. Tertiary treatment also includes the removal of nitrogen and phosphorus by additional process unit operations. Tertiary treatment processes can be physical, chemical, biological, or a combination.

B-6 Disinfection.

Disinfection is necessary to destroy pathogenic bacteria, viruses, and amoebic cysts commonly found in wastewater. Disinfection processes can be chemical (ozonation or chlorination) or physical (ultraviolet irradiation). Chemical disinfection using chlorine and, infrequently, ozone are the most widely used means of wastewater disinfection.

B-7 Sludge Treatment.

B-7.1 Sludge Stabilization.

Sludge is the settled solids accumulated and subsequently separated from the liquid during various wastewater treatment processes. Sludge handling and disposal is the most difficult, important, and costly part of the wastewater treatment process. Sludge treatment typically comprises stabilization followed by dewatering prior to disposal. Sludge can be stabilized under either anaerobic or aerobic conditions. Anaerobic sludge digestion takes place in the absence of free oxygen. The solid end product of anaerobic digestion is relatively nonputrescible and inoffensive. The off-gas produced in anaerobic sludge digestion contains about 65 percent methane and can be collected and burned as a fuel.

B-7.2 Sludge Dewatering.

Both anaerobic and aerobic digestion results in a reduction in the total volume and weight of the excess organic matter. It is often desirable, before final disposal, to reduce further the volume and weight of sludge and to change it from a liquid that is more than 95 percent water to a semisolid form. Dewatering can be accomplished by using drying beds, vacuum filters, centrifuges, filter presses, or mechanical gravity units. The dewatering operation often is enhanced by chemically conditioning the sludge before dewatering. The conditioning can include a thickening step that could be gravity or air flotation. Thermal conditioning can also be used to prepare sludge for dewatering.

B-7.3 Sludge Cake Disposal.

After sludge has been dewatered, it is identified as sludge cake. This material is disposed of by several different methods. It can be incinerated to reduce the volume to ash (approximately 10 percent of the original cake). The heat of this combustion can be utilized to produce steam for process and building heat. The cake can be composted to produce a soil conditioner. Cake can be spread directly on land for agricultural use, or it can be landfilled as a waste material.

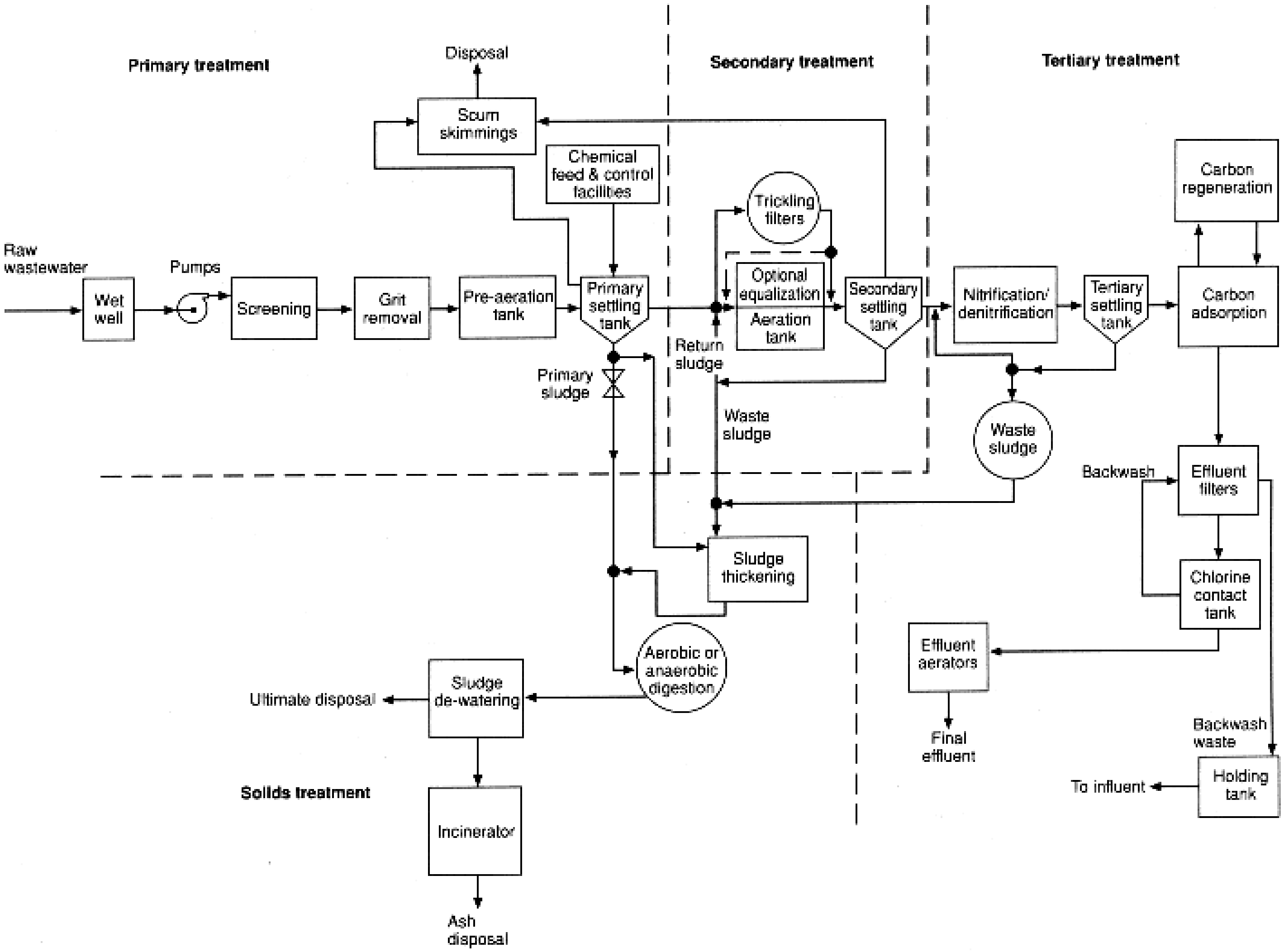


Figure B-1 Typical schematic flow and process diagram.

Appendix C Selection of Collection System Materials

This Appendix is not a part of the requirements of this NFPA document but is included for informational purposes only.

C-1 General.

Wastewater collection systems might or might not be vulnerable to the introduction of flammable liquids into the wastewater. These liquids, if lighter than water, will float and collect on the surface. The presence of these materials can present a threat to the integrity of the collection system should ignition occur.

C-2 Materials of Construction.

C-2.1

Some materials commonly used in sewer construction are vulnerable to attack from environmental conditions commonly found in collection systems, but might provide resistance to damage from fire. Other materials might be vulnerable to structural damage from fire but provide protection against long-term structural failure from corrosion.

C-2.2

For additional information on corrosion control, refer to National Association of Corrosion Engineers Recommended Practices RP01 series and the appropriate Water Environment Federation publications.

C-3 Materials Risk Assessment.

C-3.1

The materials risk assessment should include an evaluation of all factors that could potentially affect the safety and long-term functioning of the collection system. Factors to be considered should include both of the following:

(a) The potential that flammable liquids can enter the system from identifiable sources. As an example, a system serving a combined system or a system serving commercial and industrial dischargers might be more vulnerable to exposure to floating flammable materials than separate systems serving residential communities.

(b) The potential for development of conditions that might promote corrosive attack to materials vulnerable to these agents. Experience with existing conditions within the community and with existing systems with similar characteristics should be taken into full account.

C-3.2

The materials risk assessment should consider the long-term threat that these agents present to the community and to the system's ability to serve the community before a final selection is made. It is recommended that the materials risk assessment be presented to local authorities for review and comment before final selection of materials of construction is completed.

C-4 Examples.

C-4.1

Storm sewers serving locations such as residential areas and areas where significant quantities of flammable or combustible materials are not expected to enter the sewer system, sewers, and appurtenant structures could be constructed of any appropriate material.

C-4.2

Storm sewers serving locations such as commercial and industrial areas or areas where there is a possibility that significant quantities of flammable or combustible materials could enter the sewer system through illicit discharges, curb inlets, leaking underground storage tanks, or broken pipes, sewers, and associated structures might be exposed to considerable risk of fire. Materials meeting the definitions of noncombustible, limited-combustible, or low flame spread might be appropriate.

C-4.3

Where conditions or applications warrant selection of other materials for storm sewer piping and appurtenant structures, consideration to flame spread, smoke generation, and the impact that fire or explosion will have on the structural integrity and operability of the sewer system and the economic and environmental consequences of having the sewer system out of service should be included in the materials risk assessment.

C-4.4

Separate sanitary sewers serving locations such as residential areas and areas where significant quantities of flammable or combustible materials are not expected to enter the sewer system, sewers, and appurtenant structures can be constructed of any appropriate material.

C-4.5

Separate sanitary sewers serving locations such as commercial and industrial areas or areas where there is some possibility that significant quantities of flammable or combustible materials could enter the sewer system from illicit discharges, leaking underground storage tanks, or broken pipes, sewers, and appurtenant structures might be exposed to some risk of fire. Materials meeting the definitions of noncombustible, limited combustible, or low flame spread might be appropriate.

C-4.6

Where applications warrant selection of other materials for separate sanitary sewer piping and appurtenant structures, consideration to flame spread, smoke generation, and the impact that a fire or explosion will have on the structural integrity and operability of the sewer system and the economic and environmental consequences of having the sewer system out of service should be included in the materials risk assessment.

C-4.7

Where combined sewers are designed to collect both wastewater and storm water or where there is a possibility that significant quantities of flammable or combustible materials could enter the sewer system by means of curb inlets, illicit discharges, leaking underground storage tanks, or broken pipes, all sewers and other appurtenant structures can be exposed to considerable risk of fire. Materials meeting the definitions of noncombustible, limited combustible, or low flame spread might be appropriate.

C-4.8

Where conditions or applications warrant selection of other materials for combined sewer piping and appurtenant structures, consideration to flame spread, smoke generation, and the impact that a fire or explosion will have on the structural integrity and operability of the sewer system and the economic and environmental consequences of having the sewer system out of service should be included in the materials risk assessment.

Appendix D Chemical and Fuel Fire/Explosion Hazards

This Appendix is not a part of the requirements of this NFPA document but is included for informational purposes only.

D-1 General Information.

D-1.1

This appendix provides guidelines for protection against fire and explosion in the chemical and fuel storage and handling facilities. This appendix does not include gas utilization equipment, vehicle maintenance areas, or laboratories. Table D-1 summarizes the various hazards associated with chemical and fuel storage and handling facilities.

Table D-1 Chemical and Fuel Fire/Explosion Hazards

	A	B	C	D	E	F	G
	Materials and Function	**Fire and Explosion Hazard**	**Ventilation**	**Extent of Classified Area**	**NEC-Area Electrical Classification (All Class I, Group D)**	**Material of Construction for Buildings or Structures**	**Fire Protectior Measures**
1	ALCOHOL Used in some teritary treatment.	Flammable vapors	See NFPA 30.				
2	CHLORINE (Gas) Chlorination of water.	Aids combustion; oxidizer, toxic	NR	NR	Refer to Chlorine Institute.	NR (This equipment handles a corrosive chemical that necessitates the use of specific materials of construction. Special consideration should be given to these materials of construction.)	NR
3	OXYGEN (Used in aeration basins; see Chapter 3)	Aids combustion; oxidizer	See NFPA 50 and NFPA 53.			NR	NR
4	DIESEL FUEL, GASOLINE, AND MOTOR OILS Fuels for equipment.	Various	See NFPA 30 and NFPA 513.			NR	Indoor FSS and FE; Outdoor FE
5	LP-GAS	Flammable gas	NR (stored outdoors)		See NFPA 58.	NR	FE
6	OXYGEN GENERATION AND STORAGE	Aids combustion; oxidizer, oxygen-enriched areas	See NFPA 50 and NFPA 53.			NR	FSS (if indoors), H, and FE
7	OZONE GENERATION	Aids combustion; oxidizer, toxic	See NFPA 50 and NFPA 53.			NR	FSS (if indoors), H, and FE
8	ACTIVATED CARBON (Powdered or pulverized)	Combustible	NR	NR	NR	NR	NR

FE — Portable fire extinguisher FSS — Fire suppression system (automatic sprinkler, water spray, foam, gaseous, or dry chemical)
H — Hydrant protection (*see 5-2.4*) NEC — (*See NFPA 70, National Electrical Code*)
NR — No requirement

D-1.2

This appendix also contains additional information on specific areas or unit operations associated with storage and handling of chemicals and fuels commonly used in municipal wastewater treatment plants.

D-2 Sources of Hazards.

(*See Table D-2.*)

D-2.1 Fuel Gases.

Fuel gases include natural gas, manufactured gas, sewer gas, liquefied petroleum gas—air mixtures, liquefied petroleum gas in the vapor phase, mixtures of these gases, and floating flammable liquids. Some of these gases have specific gravities lower than that of air so that, when released, they will rapidly rise and diffuse above the point of leakage. Flammable mixtures are produced when these gases are mixed with air within certain limits. They can be considered as suffocating gases.

D-2.2 Sludge Gases.

These flammable gases result from the fermentation or anaerobic decomposition of organic matter. Explosive conditions (especially concerning compression and storage) can result when these gases are mixed with air.

D-2.3 Sewer Gases.

These flammable gases result from the fermentation or decomposition of organic matter. Explosive conditions (especially concerning the screening, degritting, and primary clarification processes) might result when these gases are mixed with air.

D-2.4 Unit Processes.

Special consideration should be given to the following unit processes associated with solids treatment:

(a) Scum pits collect scum, grease, and other floating flammable liquids from the surface of sedimentation tanks. Special consideration should be given to equipment located in these areas because of potential explosion and fire hazards.

(b) Sumps and tanks that collect drainage from anaerobic sludge treatment processes or that store, mix, and blend sludge might also collect significant volumes of sludge gas. Special consideration should be given to equipment located in these areas because of the potential for explosion.

(c) Anaerobic digesters are unit processes specifically designed to produce sludge gas from the fermentation or anaerobic decomposition of organic matter. The sludge gas normally contains significant volumes of methane as a by-product of the anaerobic digestion process. Special consideration should be given to equipment located in and around anaerobic digesters because of the potential for explosion.

(d) Solvent extraction and dehydration processes can produce a very dry organic dust as a by-product. Special consideration should be given to equipment located in dust-handling areas because of the potential for explosion.

(e) Incinerators used to burn scum or sludge cake are ignition sources when in operation. Special consideration should be given in construction of incineration buildings and in storage of combustible materials in incineration areas.

(f) Sludge dewatering and sludge cake conveyance equipment generate sludge cake and convey it to its final destination (incineration, landfill, etc.). Dried cake can be a combustible material. Special consideration should be given in construction, operation, maintenance, and housekeeping of the equipment and surrounding areas.

(g) Pumping stations that handle raw wastewater should be classified in the same manner as wastewater pumping stations (*see Chapter 2*). In-plant pumping stations should be classified depending upon their location in the process train and the type of material handled. Restrictive classifications are generally not necessary for pumping stations that handle fully treated wastewater.

(h) Grit chambers or screening equipment that is housed in a building or in below-grade pits might be subject to the same fire and explosion hazards as pumping station wet wells.

(i) Imhoff tanks and other similar processes can combine the wastewater liquids and solids treatment streams in a single vessel. Special consideration should be given to equipment located in or around Imhoff tanks or similar processes because of the generation of methane gas from anaerobic solids digestion processes within the vessel and the possibility of volatile substances being released from the wastewater.

(j) The primary sedimentation tank might collect and concentrate floating flammable liquids.

(k) Secondary and tertiary sedimentation tanks and aeration tanks not preceded by primary sedimentation can be subject to the same fire and explosion hazards as primary sedimentation tanks because of the potential of floating flammable liquids collecting on the surface. Where bypassing of primary sedimentation is possible, although not normally utilized, secondary and tertiary sedimentation tanks and aeration tanks might not be subject to the same fire and explosion potential as primary sedimentation.

(l) Unit processes employing oxygen-enriched atmospheres necessitate special consideration. Covered facilities might be unclassified above the covering deck; however, any equipment or instrumentation housed under the cover within the reactor space should be suitable for exposure to volatile hydrocarbons in an oxygen-enriched atmosphere. Oxygen is not itself flammable; however, increased concentrations of oxygen greatly increase the fire hazard. Oxygen aeration tanks and other similar processes should be equipped with continuously operating hydrocarbon LEL monitoring devices that will automatically cut off oxygen supply and purge reactor gases with atmospheric air when 10 percent LEL conditions are registered.

(m) Galleries and other connecting structures that contain pipes transporting flammable gases or liquids necessitate special consideration in design and fire protection.

(n) Plastic media or wood for trickling filters, rotating biological contactors, bio-towers, and other fixed film systems are not a significant hazard in normal operations; however, these materials are normally classified as combustible and can contribute a considerable fuel load if ignited under certain conditions, such as during maintenance and construction. Some fixed film treatment systems are anaerobic and produce a combustible gas by-product, which aggravates the hazard for such enclosures containing these materials.

D-2.5 Chemicals.

Wastewater treatment plants use a variety of gaseous, solid, and liquid chemicals that by themselves or when mixed with oxygen or other chemicals can be a potential source of fire or explosion, or both. Additional information can be found in NFPA 49, *Hazardous Chemicals Data*; NFPA 497A, *Recommended Practice for Classification of Class I Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas*; and NFPA 45, *Standard on Fire Protection for Laboratories Using Chemicals*. Chemicals should be handled, processed, and stored in a manner that eliminates or significantly reduces the hazard to the wastewater treatment facility and personnel and is acceptable to the authority having jurisdiction. Chemicals should be properly labeled to identify the materials and hazards, and material safety data sheets should be made available to all personnel.

D-2.6 Hazardous Gases.

Sewer and sludge gas are flammable gases generated by the fermentation or decomposition of organic matter. Explosive conditions (especially concerning screening, degritting, primary clarification, and the anaerobic digestion process) can result when these gases are mixed with air. Specialty gases utilized for (a) laboratory analysis and instrumentation calibration (hydrogen, methane, etc.), (b) wastewater treatment plant unit processes (chlorine, ozone, etc.), and (c) welding operations (acetylene, oxygen, etc.) can form flammable/explosive conditions when either acting alone or mixed with other gaseous organic substances. Fuel gases including natural gas, manufactured gas, and liquefied petroleum gas used as fuels for wastewater treatment plant equipment can cause flammable/explosive conditions when improperly used, handled, or stored. Appropriate measures should be taken to prevent the accumulation of hazardous gases, including ventilation, proper storage, and safe handling/distribution systems. For additional guidance, see NFPA 55, *Standard for the Storage, Use, and Handling of Compressed and Liquefied Gases in Portable Cylinders*, and NFPA 59A, *Standard for the Production, Storage, and Handling of Liquefied Natural Gas (LNG)*. In processes where explosive mixtures cannot be prevented, explosion venting or protection systems should be provided. See NFPA 68, *Guide for Venting of Deflagrations*, and NFPA 69, *Standard on Explosion Prevention Systems,* for additional guidance.

D-2.7 Liquids.

Disposal of waste chemical products through sewers and into wastewater treatment plants and disposal of waste chemical products and scum skimmed from sedimentation tanks can be potential sources or contributing causes of fire and explosive conditions. Hydrocarbon liquids such as gasoline, kerosene, oils, and various chemicals either sent to sewers and drains or used for various applications at wastewater treatment plants can also provide flammable vapor concentrations at certain locations. For additional information, see NFPA 321, *Standard on Basic Classification of Flammable and Combustible Liquids*, and NFPA 329, *Recommended Practice for Handling Underground Releases of Flammable and Combustible Liquids*. Areas of wastewater treatment plants as identified and classified in Tables 2 through 4 (especially areas of primary treatment) should be protected as flammable liquid hazards.

D-2.8 Finely Divided Solids and Dusts.

Finely divided solids used in various wastewater treatment processes (especially sludge dehydration processing) or dust by-products produced by such processes can be combustible or cause potential flammable and explosive conditions. Process areas should be cleaned on a regular schedule to prevent the accumulation of hazardous concentrations of dust. Equipment handling finely divided solids should be designed and installed in a manner that protects against the hazards of fire and explosion. Additional information can be found in NFPA 61, *Standard for the Prevention of Fire and Dust Explosions in Agricultural and Food Products Facilities;* NFPA 91, *Standard for Exhaust Systems for Air Conveying of Materials;* and NFPA 8503, *Standard for Pulverized Fuel Systems*.

D-2.9 Materials.

Materials used in wastewater treatment plants due to humid or corrosive atmospheres, including wood, plastic, fiberglass-reinforced plastics (FRPs), paints and coatings, insulating material, and furnishings, can be combustible, limited combustible, or low flame spread under certain conditions. Some of these materials can present a considerable fuel load if ignited. Buildings and structures should be provided with fire protection in accordance with Chapter 6 of this document. Areas where materials are stored should be provided with appropriate fire protection approved by the authority having jurisdiction. For additional guidance, see NFPA 13, *Standard for the Installation of Sprinkler Systems;* NFPA 231, *Standard for General Storage;* and NFPA 231C, *Standard for Rack Storage of Materials*.

Table D-2 Gases Commonly Found in Wastewater Treatment

Name (chemical formula)	Explosive Limits (% vol.) LEL	UEL	Density[1] Heavier/Lighter than Air	Sources
Ammonia[3] (NH_3)	16	25	L	— Storage tank leaks
Chlorine[2] (Cl_2)	nonflammable		H	— Disinfection processes — Storage tanks
Gasoline[3] (C_5H_{12} - C_9H_{20})	1.3	7.1	H	— Storage tanks — Tank truck spills
Hydrogen Chloride (HCl)	nonflammable		H	— Storage tank leaks — Ceramic diffuser cleaning
Hydrogen Sulfide[5, 6] (H_2S)	4.0	44	H	— Sewer gas — Sludge gas
Natural Gas[5]	3.8–6.5	13–17	L	— Gas piping leaks
Nitrogen (N_2)	nonflammable		L	— Storage tanks — Oxygen generation processes — Denitrification processes
Oxygen[2] (O_2)	nonflammable		H	— Generation of oxygen on-site — Activated sludge processes — Storage tanks — Sludge processes
Ozone[2] (O_3)	nonflammable		H	— Disinfection processes — On-site generation processes
Sewer Gas[3]	5.3	19.3	H	— Sewer systems
Sludge Gas[4]	5	15	L	— Sludge digestion processes
Sulfur Dioxide (SO_2)	nonflammable		H	— Dechlorination processes — Storage tanks

NOTE 1: The table lists the physical properties at standard temperature and pressure. Due to actual field conditions, these gases might disperse and might be present throughout the structure.
NOTE 2: These gases accelerate combustion.
NOTE 3: Contains approximately 70 percent carbon dioxide, 5 percent methane, and 25 percent other gases (source: US EPA).
NOTE 4: Contains approximately 65 percent methane, 30 percent carbon dioxide, and 5 percent other gases (source: US EPA).
NOTE 5: Source: NFPA 325, *Guide to Fire Hazard Properties of Flammable Liquids, Gases, and Volatile Solids*.
NOTE 6: Rarely reaches explosive concentration in wastewater treatment plants.

D-3 Conditions for and Sources of Ignition.

The potential ignition of flammable gases, liquids, and solids (including dusts) that can be found at a wastewater treatment plant is limited by certain fundamental conditions. Gases and generated vapors need to be mixed with air or an oxidizer to form a flammable mixture that needs heat of sufficient intensity for ignition. The ignition temperature of a combustible solid is influenced by the rates of airflow and heating as well as the geometry of the rates of airflow and heating and the geometry of the solid. Ignition can result from one or more of the following causes: (a) open flames or hot surfaces, (b) electrical arc, (c) sparks, or (d) chemical reaction.

D-3.1 Open Flames and Hot Surfaces.

Open flames and hot surfaces might be encountered during normal operation, repair and maintenance operations, or with malfunctioning equipment and appliances within a wastewater treatment plant. Sources of ignition might include welding tasks, boilers, incinerators, kerosene-type lanterns, internal combustion engines, and smoking by personnel. Equipment producing open flames or hot surfaces capable of producing ignition should be properly installed, maintained, and isolated from potential hazards. For additional guidance, see NFPA 31, *Standard for the Installation of Oil-Burning Equipment;* NFPA 37, *Standard for the Installation and Use of Stationary Combustion Engines and Gas Turbines;* NFPA 82, *Standard on Incinerators and Waste and Linen Handling Systems and Equipment;* NFPA 8501, *Standard for Single Burner Boiler Operation;* and NFPA 8502, *Standard for the Prevention of Furnace Explosions/Implosions in Multiple Burner Boiler-Furnaces*. Smoking should be prohibited in all hazardous areas.

D-3.2 Electrical Arc.

Sustained arcing faults can cause extensive damage to electrical switchgear and motor control centers. This might provide sufficient heat to ignite flammable gases or vapors present or generated as a result of the arc (pyrolysis of insulating material). Electrical equipment should be properly maintained in good operating condition. Faulty equipment should be removed from service. See NFPA 70B, *Recommended Practice for Electrical Equipment Maintenance*, for additional guidance.

D-3.3 Sparks.

Sparks generated by (a) defective or worn electrical and mechanical equipment, (b) activities performed by personnel, and (c) static electricity can be a source of ignition for gases of flammable vapors. Fire prevention practices to eliminate or control this hazard should include a prevention maintenance program, the use of nonsparking tools, and the provision of bonding and grounding conductors in hazardous areas. See NFPA 77, *Recommended Practice on Static Electricity*, for additional guidance.

D-3.4 Chemical Reaction.

Fire and explosion can be the result of the chemical reaction of substances that are (a) introduced in the wastewater treatment plant influent, (b) used for laboratory analysis, (c) necessary to various unit processes, and (d) produced as by-products. Potential chemical reactions can cause hazardous conditions that range in severity from the generation of flames (spontaneous combustion) to explosion. Chemicals should be identified and stored in a proper manner. Noncompatible chemical combinations should be identified, and segregated storage should be provided. See NFPA 491M, *Manual of Hazardous Chemical Reactions*, for additional information.

D-4 Mitigation Measures.

Mitigation of either hazards or potential ignition sources is achieved with a commonly preferred method of copious flushing with air (ventilation). In the event that a foreign combustible material enters the sewer system, removal by vacuum or coverage with foam might become necessary. Whenever possible, such entry is to be avoided by containment and adsorption. Appropriate use of a combustible gas detector is warranted as a minimal precaution preceding personnel entry into a collection system. The presence of toxic gases should be considered when entering any confined space.

D-5 Storage and Production Facilities.

Special consideration should be given to the following facilities associated with the storage and production of chemicals and fuels used in the treatment of municipal wastewater.

D-5.1

Oxygen generation, storage, and handling facilities necessitate special consideration. Although oxygen is not itself flammable, it does support combustion, and increased concentration of oxygen greatly increases the fire hazard. See NFPA 50, *Standard for Bulk Oxygen Systems at Consumer Sites*.

D-5.2

Ozone is generated by passing oxygen through an electric field. As with oxygen-generating facilities, there is an increased fire hazard. Ozonation facilities necessitate special consideration because of the extreme heat and electric field generated and the additional concern for the extreme corrosivity and toxicity of ozone. See NFPA 50, *Standard for Bulk Oxygen Systems at Consumer Sites*.

D-5.3

Chlorine is a very reactive chemical and necessitates special consideration in storing and handling. Chlorine in combination with other chemicals can produce sufficient heat to cause combustion of flammable materials. Chlorine and other reactive chemicals should always be stored separately. (*See information from the Chlorine Institute*.)

D-5.4

Activated carbon stored in bulk or in bags can provide a source of combustible material that can add a considerable fuel load if ignited. Special consideration should be given to equipment located in activated carbon-handling areas or activated carbon storage facilities because of the potential for fire.

Appendix E List of Associations and Abbreviations

This Appendix is not a part of the recommendations of this NFPA document but is included for informational purposes only.

ANSI American National Standards Institute, 1430 Broadway, New York, NY 10018.

EPA Environmental Protection Agency, Municipal Technology Branch (4204), 401 M Street, SW, Washington, DC 20460.

FM Factory Mutual Research Corporation, 1151 Boston-Providence Turnpike, Norwood, MA 02062.

NFPA National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.

OSHA Occupational Safety and Health Administration, U.S. Department of Labor, 200 Constitution Avenue, NW, Washington, DC 20001.

UL Underwriters Laboratories Inc., 333 Pfingsten Road, Northbrook, IL 60062.

WEF Water Environment Federation, 601 Wythe Street, Alexandria, VA 22314-1994 (previously WPCF, Water Pollution Control Federation).

Appendix F Referenced Publications

F-1

The following documents or portions thereof are referenced within this standard for informational purposes only and thus are not considered part of the requirements of this document. The edition indicated for each reference is the current edition as of the date of the NFPA issuance of this document.

F-1.1 NFPA Publications.

National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.

NFPA 1, *Fire Prevention Code*, 1992 edition.

NFPA 13, *Standard for the Installation of Sprinkler Systems*, 1994 edition.

NFPA 30, *Flammable and Combustible Liquids Code*, 1993 edition.

NFPA 31, *Standard for the Installation of Oil-Burning Equipment*, 1992 edition.

NFPA 37, *Standard for the Installation and Use of Stationary Combustion Engines and Gas Turbines*, 1994 edition.

NFPA 45, *Standard on Fire Protection for Laboratories Using Chemicals*, 1991 edition.

NFPA 49, *Hazardous Chemicals Data*, 1994 edition.

NFPA 50, *Standard for Bulk Oxygen Systems at Consumer Sites*, 1990 edition.

NFPA 51B, *Standard for Fire Prevention in Use of Cutting and Welding Processes*, 1994 edition.

NFPA 53, *Guide on Fire Hazards in Oxygen-Enriched Atmospheres*, 1994 edition.

NFPA 54, *National Fuel Gas Code*, 1992 edition.

NFPA 55, *Standard for the Storage, Use, and Handling of Compressed and Liquefied Gases in Portable Cylinders*, 1993 edition.

NFPA 58, *Standard for the Storage and Handling of Liquefied Petroleum Gases*, 1995 edition.

NFPA 59A, *Standard for the Production, Storage, and Handling of Liquefied Natural Gas (LNG)*, 1994 edition.

NFPA 61, *Standard for the Prevention of Fire and Dust Explosions in Agricultural and Food Products Facilities*, 1995 edition.

NFPA 68, *Guide for Venting of Deflagrations*, 1994 edition.

NFPA 69, *Standard on Explosion Prevention Systems*, 1992 edition.

NFPA 70, *National Electrical Code*, 1996 edition.

NFPA 70B, *Recommended Practice for Electrical Equipment Maintenance*, 1994 edition.

NFPA 77, *Recommended Practice on Static Electricity*, 1993 edition.

NFPA 82, *Standard on Incinerators and Waste and Linen Handling Systems and Equipment*, 1994 edition.

NFPA 91, *Standard for Exhaust Systems for Air Conveying of Materials*, 1995 edition.

NFPA *101*, *Life Safety Code*, 1994 edition.

NFPA 204M, *Guide for Smoke and Heat Venting*, 1991 edition.

NFPA 231, *Standard for General Storage*, 1995 edition.

NFPA 231C, *Standard for Rack Storage of Materials*, 1991 edition.

NFPA 255, *Standard Method of Test of Surface Burning Characteristics of Building Materials*, 1990 edition.

NFPA 259, *Standard Test Method for Potential Heat of Building Materials*, 1993 edition.

NFPA 321, *Standard on Basic Classification of Flammable and Combustible Liquids*, 1991 edition.

NFPA 325, *Guide to Fire Hazard Properties of Flammable Liquids, Gases, and Volatile Solids*, 1994 edition.

NFPA 328, *Recommended Practice for the Control of Flammable and Combustible Liquids and Gases in Manholes, Sewers, and Similar Underground Structures*, 1992 edition.

NFPA 329, *Recommended Practice for Handling Underground Releases of Flammable and Combustible Liquids*, 1992 edition.

NFPA 491M, *Manual of Hazardous Chemical Reactions*, 1991 edition.

NFPA 497A, *Recommended Practice for Classification of Class I Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas*, 1992 edition.

NFPA 497B, *Recommended Practice for the Classification of Class II Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas*, 1991 edition.

NFPA 513, *Standard for Motor Freight Terminals*, 1994 edition.

NFPA 600, *Standard on Industrial Fire Brigades*, 1992 edition.

NFPA 8501, *Standard for Single Burner Boiler Operation*, 1992 edition.

NFPA 8502, *Standard for the Prevention of Furnace Explosions/Implosions in Multiple Burner Boilers*, 1995 edition.

NFPA 8503, *Standard for Pulverized Fuel Systems*, 1992 edition.

F-1.2 Other Publications.

F-1.2.1 ANSI Publications. American National Standards Institute, 1430 Broadway, New York, NY 10018.

ANSI/IEEE 268, *Metric Practices,* 1992.

ANSI/ISA RP 12.67, *Installation of Intrinsically Safe Instrument Systems in Class I Hazardous Locations,* 1967.

F-1.2.2 Chlorine Institute Publication. The Chlorine Institute, 342 Madison Avenue, New York, NY 10017.

Properties of Chlorine.

F-1.2.3 NACE Publications. National Association of Corrosion Engineers, 1400 South Creek Drive, Houston, TX 77084.

Recommended Practices RP01 series.

F-1.2.4 UL Publication. Underwriters Laboratories Inc., 333 Pfingsten Road, Northbrook, IL 60062.

Hazardous Location Equipment Directory.

F-1.2.5 U.S. Government Publications. U.S. Government Printing Office, Washington, DC 20402.

40 CFR, 761.30.

OSHA 29 CFR, 1910.156.

F-2 Additional Reading.

1. Great Lakes Upper Mississippi Board of State Public Health and Environmental Managers, *Recommended Standards for Wastewater Facilities (10 State Standard),* Health Education Services, Albany, NY, 1990.
2. Igor J. Kavassik, William C. Krutzsch, Warren H. Fraser, and Joseph Messina, *Pump Handbook*, McGraw-Hill, Inc., New York, 1986.
3. Metcalf and Eddy, Inc., *Wastewater Engineering: Collection and Pumping of Wastewater, McGraw-Hill, Inc*., New York, 1981.
4. Metcalf and Eddy, Inc., *Wastewater Engineering: Treatment, Disposal and Reuse (3rd ed.), McGraw-Hill, Inc*., New York, 1985.
5. Robert L. Sanks, George Tchobanoglous, Donald Newton, Bayard E. Bosserman, and Garr M. Jones, *Pumping Station Design*, Butterworth Publishers, Stoneham, MA, 1989.
6. Water Pollution Control Federation, *Wastewater Treatment Plant Design*, *Manual of Practice #8*, Alexandria, VA, 1990.
7. Water Pollution Control Federation, *Wastewater Treatment Plant Operations*, *Manual of Practice #11*, Alexandria, VA 1990.

Formal Interpretation

NFPA 820

Fire Protection in Wastewater Treatment and Collection Facilities

1995 Edition

Reference : Tables 2, 3, and 4
F.I. 92-1

Background: In Tables 2, 3, and 4, footnote code A is defined as "Ventilated at less than 12 air changes per hour."

Question 1: Does this definition include mechanically ventilated at any rate less than 12 air changes per hour (including 1 air change per hour or less)?

Answer: Yes.

Question 2: Does this definition include ventilated with a static vent (without mechanical ventilation)?

Answer: Yes.

Issue Edition: 1992
Reference: Tables 2, 3, 4, and 5
Issue Date: May 11, 1992
Effective Date: June 1, 1992

NFPA 850

1996 Edition

Recommended Practice for Fire Protection for Electric Generating Plants and High Voltage Direct Current Converter Stations

1996 Edition

This edition of NFPA 850, *Recommended Practice for Fire Protection for Electric Generating Plants and High Voltage Direct Current Converter Stations*, was prepared by the Technical Committee on Electric Generating Plants and acted on by the National Fire Protection Association, Inc., at its Fall Meeting held November 13-15, 1995, in Chicago, IL. It was issued by the Standards Council on January 12, 1996, with an effective date of February 2, 1996, and supersedes all previous editions.

Changes other than editorial are indicated by a vertical rule in the margin of the pages on which they appear. These lines are included as an aid to the user in identifying changes from the previous edition.

This edition of NFPA 850 was approved as an American National Standard on February 2, 1996.

Origin and Development of NFPA 850

The Committee on Non-Nuclear Power Generating Plants was organized in 1979 to have primary responsibility for documents on fire protection for non-nuclear electric generating plants. Begun early in 1980, the first edition of NFPA 850 was officially released in 1986 as the *Recommended Practice for Fire Protection for Fossil Fueled Steam Electric Generating Plants*.

The second edition of NFPA 850 was issued in 1990 under the revised title of *Recommended Practice for Fire Protection for Fossil Fueled Steam and Combustion Turbine Electric Generating Plants*. This second edition incorporated a new Chapter 6 on the identification and protection of hazards for combustion turbines.

In 1991 the Committee changed its name to the Technical Committee on Electric Generating Plants. This simplified name was made to reflect the Committee's scope to cover all types of electric generating plants except nuclear.

The 1992 edition of NFPA 850 incorporated a new Chapter 7 on alternative fuel electric generating plants. As part of these changes, the document title was revised to the *Recommended Practice for Fire Protection for Electric Generating Plants*. Various other technical and editorial changes were also made.

This 1996 edition of the standard added a new Chapter 8 on Fire Protection for High Voltage Direct Current (HVDC) converter stations. In addition, the title was changed to *Recommended Practice for Fire Protection for Electric Generating Plants and High Voltage Direct Current Converter Stations* to incorporate the new chapter.

Technical Committee on Electric Generating Plants

Leonard R. Hathaway, *Chair*
M&M Protection Consultants, IL

Kenneth W. Dungan, *Vice Chair*
HSB Professional Loss Control Inc., TN

Lee T. Warnick, *Secretary*

Virginia Power Co., VA

Michael L. Alford, Stone Container Corp., IL

Thomas L. Allen, U.S. Fidelity & Guaranty Co., MD
Rep. American Insurance Services Group, Inc.

Donald C. Birchler, FP&C Consultants Inc., MO

Bernhard G. Bischoff, Figgie Fire Protection Systems, IL
Rep. Fire Suppression Systems Assn.

Harold D. Brandes, Jr., Duke Power Co., NC

Stanley J. Chingo, VECTRA Technologies, Inc., IL

Thomas C. Clayton, Black & Veatch, MO

Harry M. Corson, Cerberus Pyrotronics, NJ
Rep. Nat'l Electrical Mfrs. Assn.

Phillip A. Davis, Kemper Nat'l Insurance Companies, PA

Donald A. Diehl, Alison Control Inc., NJ

Paul H. Dobson, Factory Mutual Research Corp., MA

Don Drewry, Hartford Steam Boiler Inspection & Insurance Co., NJ

James F. Foley, New York Power Authority, NY

Ismail M. Gosla, Fluor Daniel, CA

Dwight S. Hull, Tennessee Valley Authority, TN

Everett C. Hume, Industrial Risk Insurers, CT
Rep. Industrial Risk Insurers

John W. Koester, Johnson & Higgins, MD

Amjad M. Mian, Manitoba Hydro, Canada

James G. Pittman, Seminole Electric Cooperative Inc., FL

Gregory W. Powell, Baltimore Gas & Electric Co., MD

John G. Puder, F. E. Moran Inc., IL

Joseph F. Scarduzio, Sr., Raytheon Engr & Constructors, PA

Omer Semen, Raytheon Engr & Constructors, NY

William D. Snell, TU Services Inc., TX

Steven F. Vieira, Grinnell Corp., RI
Rep. Nat'l Fire Sprinkler Assn.

Lynn C. Wall, Sedgwick James of Georgia, GA

R. L. Welch, Cincinnati Gas & Electric Co., OH
Rep. Electric Light Power Group/Edison Electric Inst.

Alternates

Patrick T. Borns, McDaniel Fire Systems Inc., IN
(Alt. to B. G. Bischoff)

John K. Bouchard, Sedgwick James of New England, MA
(Alt. to L. C. Wall)

Fernando A. Caycedo, Raytheon Engr & Constructors, GA
(Alt. to O. Semen)

James M. Connolly, M&M Protection Consultants, IL
(Alt. to L. R. Hathaway)

Robert E. Dundas, Factory Mutual Research Corp., MA
(Alt. to P. H. Dobson)

Rickey L. Johnson, Cigna Loss Control Services, CT
(Alt. to T. L. Allen)

Robert A. Kuchinski, Hartford Steam Boiler Inspection & Insurance Co., CT
(Alt. to D. Drewry)

Yuvonne L. Moore, Stone Container Corp., IL
(Alt. to M. L. Alford)

James F. Mulvoy, Alison Control Inc., IL
(Alt. to D. A. Diehl)

Charles R. Prasso, Industrial Risk Insurers, CT
(Alt. to E. C. Hume)

Allan P. Rhodes, VECTRA Technologies, Inc., CA

Committee Scope: This Committee shall have primary responsibility for documents on fire protection for electric generating plants and high voltage direct current (HVDC) converter stations, except for electric generating plants using nuclear fuel.

NFPA 850

Recommended Practice for Fire Protection for Electric Generating Plants and High Voltage Direct Current Converter Stations

1996 Edition

NOTICE: An asterisk (*) following the number or letter designating a paragraph indicates explanatory material on that paragraph in Appendix A.
Information on referenced publications can be found in Chapter 10 and Appendix E.

Chapter 1 Introduction

1-1 Scope.

This document provides recommendations (not requirements) for fire prevention and fire protection for electric generating plants and high voltage direct current converter stations, except as follows: nuclear power plants are addressed in NFPA 803, *Standard for Fire Protection for Light Water Nuclear Power Plants*; hydroelectric plants are addressed in NFPA 851, *Recommended Practice for Fire Protection for Hydroelectric Generating Plants*; and combustion turbine and internal combustion engine units of 7500 hp or less are addressed in NFPA 37, *Standard for the Installation and Use of Stationary Combustion Engines and Gas Turbines*.

1-2 Purpose.

This document is prepared for the guidance of those charged with the design, construction, operation, and protection of gas, oil, alternative fuels (i.e., municipal solid waste, refuse derived fuel, biomass, rubber tires, and other combustibles) or coal-fired steam electric generating plants, combustion turbine and internal combustion engine electric generating plants, and high voltage direct current converter stations. This document provides fire prevention and fire protection recommendations for the safety of construction and operating personnel, the physical integrity of plant components, and the continuity of plant operations. Nothing in this document is intended to restrict new technologies or alternative arrangements.

1-3 Application.

1-3.1

This document is intended for use by persons knowledgeable in the application of fire protection for electric generating plants and high voltage direct current converter stations.

1-3.2

The recommendations contained in this document are intended for new installations only, as the application to existing installations may not be practicable.

1-3.3

It should be recognized that rigid uniformity of generating station design and operating procedures does not exist and that each facility will have its own special conditions that impact on the nature of the installation. Many of the specific recommendations herein may require modification after due consideration of all local factors involved.

1-4 Definitions.

Alternative Fuels. Solid fuels such as municipal solid waste (MSW), refuse derived fuel (RDF), biomass, rubber tires, and other combustibles that are used instead of gas, oil, or coal in a boiler to produce steam for the generation of electrical energy.

Approved.* Acceptable to the authority having jurisdiction.

Authority Having Jurisdiction.* The organization, office, or individual responsible for approving equipment, an installation, or a procedure.

Biomass. A boiler fuel manufactured by means of a process that includes storing, shredding, classifying, and conveying of forest and agricultural byproducts (e.g., woodchips, rice hulls, sugar cane, etc.).

Combustible. Any material that does not comply with the definition of either noncombustible or limited combustible.

Combustible Liquid. A liquid having a flash point at or above 100°F (37.8°C). (*See NFPA 30, Flammable and Combustible Liquids Code.*)

Fire Barrier. A fire barrier is a continuous membrane, either vertical or horizontal, such as a wall or floor assembly, that is designed and constructed with a specified fire resistance rating to limit the spread of fire and that will also restrict the movement of smoke. Such barriers may have protected openings.

Fire Loading. The amount of combustibles present in a given area, expressed in Btu/ft^2 (kJ/m^2).

Fire Point. The lowest temperature at which a liquid in an open container will give off sufficient vapors to burn once ignited. It generally is slightly above the flash point.

Fire Prevention. Measures directed toward avoiding the inception of fire.

Fire Protection. Methods of providing for fire control or fire extinguishment.

Fire Protection Rating. The time, in minutes or hours, that materials and assemblies used as opening protection have withstood a fire exposure as established in accordance with test procedures of NFPA 252, *Standard Methods of Fire Tests of Door Assemblies*, and NFPA 257, *Standard on Fire Test of Window and Glass Block Assemblies*, as applicable.

Fire Rated Penetration Seal. An opening in a fire barrier for the passage of pipe, cable, duct, etc., that has been sealed so as to maintain a barrier rating.

Fire-Resistant Fluid. A listed hydraulic fluid or lubricant that is difficult to ignite due to its high fire point and autoignition temperature and that does not sustain combustion due to its low heat of combustion.

Fire Resistance Rating. The time, in minutes or hours, that materials or assemblies have withstood a fire exposure as established in accordance with the test procedures of NFPA 251, *Standard Methods of Tests of Fire Endurance of Building Construction and Materials*.

Flammable Liquid. Any liquid having a flash point below 100°F (37.8°C) and having a vapor pressure not exceeding 40 psia (276 kPa) absolute pressure at 100°F (37.8°C). (*See NFPA 30, Flammable and Combustible Liquids Code.*)

High Fire Point Liquid. A combustible dielectric liquid listed as having a fire point of not less than 572°F (300°C).

High Voltage Direct Current (HVDC) Converter Station. A facility that functions as an electrical rectifier (ac-dc) or an inventor (dc-ac) to control and transmit power in a high voltage network. There are two types of HVDC valves: the mercury arc valve and the present day technology solid state thyristor valve. Both types of valves present a fire risk due to high voltage equipment that consists of oil-filled converter transformers, wall bushings, and capacitors in addition to various polymeric components.

Interior Finish. The exposed interior surfaces of buildings including, but not limited to, fixed or movable walls and partitions, columns, and ceilings. Interior finish materials are grouped in the following classes:

Class A Interior Finish. Materials having flame spread 0-25, smoke developed 0-450 when tested in accordance with NFPA 255, *Standard Method of Test of Surface Burning Characteristics of Building Materials*. Includes any material classified at 25 or less on the flame spread test scale and 450 or less on the smoke test scale when any element thereof, when tested, does not continue to propagate fire.

Class B Interior Finish. Materials having flame spread 26-75, smoke developed 0-450 when tested in accordance with NFPA 255, *Standard Method of Test of Surface Burning Characteristics of Building Materials*. Includes any material classified at more than 25, but not more than 75, on the flame spread test scale and 450 or less on the smoke test scale.

Labeled. Equipment or materials to which has been attached a label, symbol, or other identifying mark of an organization that is acceptable to the authority having jurisdiction and concerned with product evaluation that maintains periodic inspection of production of labeled equipment or materials and by whose labeling the manufacturer indicates compliance with appropriate standards or performance in a specified manner.

Less Flammable Liquid. A combustible dielectric liquid listed as having a fire point of not less than 572°F (300°C).

Limited Combustible. As applied to a building construction material, a material, not complying with the definition of noncombustible material, that in the form in which it is used has a potential heat value not exceeding 3500 Btu/lb (8.14×10^6 J/kg) (*see NFPA 259, Standard Test Method for Potential Heat of Building Materials*), and complies with one of the following paragraphs (a) or (b):

(a) Materials having a structural base of noncombustible material with a surfacing not exceeding a thickness of $^1/_8$ in. (3.175 mm) that has a flame spread rating not greater than 50.

(b) Materials, in the form and thickness used, other than as described in (a), having neither a flame spread rating greater than 25 nor evidence of continued progressive combustion, and of such composition that the surfaces that would be exposed by cutting through the material on any plane would have neither a flame spread rating greater than 25 nor evidence of continued progressive combustion as tested in accordance with NFPA 255, *Standard Method of Test of Surface Burning Characteristics of Building Materials*.

Materials subject to increase in combustibility or flame spread rating beyond the limits herein established through the effects of age, moisture, or other atmospheric condition are considered combustible.

Listed.* Equipment or materials included in a list published by an organization acceptable to the authority having jurisdiction and concerned with product evaluation that maintains periodic inspection of production of listed equipment or materials and whose listing states either that the equipment or material meets appropriate standards or has been tested and found suitable for use in a specified manner.

Mass Burn. A process in which municipal solid waste is hauled directly to a tipping floor or storage pit and then is used as a boiler fuel without any special processing.

Municipal Solid Waste (MSW). Solid waste materials consisting of commonly occurring residential and light commercial waste.

Noncombustible. A material that in the form in which it is used and under the conditions anticipated will not aid combustion or add appreciable heat to an ambient fire. Materials when tested in accordance with ASTM E 136, *Standard Test Method for Behavior of Materials in a Vertical Tube Furnace at 750°C*, and conforming to the criteria contained in Section 7 of the referenced standard are considered as noncombustible.

Nonflammable Fluid. A nonflammable dielectric fluid that does not have a flash point and is not flammable in air.

Refuse Derived Fuel (RDF). A boiler fuel manufactured by means of a process that includes storing, shredding, classifying, and conveying of municipal solid waste.

Should. Indicates a recommendation or that which is advised but not required.

1-5 Units.

Metric units in this document are in accordance with the International System of Units, which is officially abbreviated SI in all languages. For a full explanation, see ASTM E 380/ANSI Z210.1, *Metric Practice Guide*.

Chapter 2 Administrative Controls

2-1 General.

2-1.1

This chapter provides recommended criteria for the development of administrative procedures and controls necessary for the execution of the fire prevention and fire protection activities and practices for electric generating plants and high voltage direct current converter stations.

2-1.2

The administrative controls recommended in this chapter should be reviewed and updated periodically.

2-1.3

The intent of this chapter can be met by incorporating the features of this chapter in the plant's operating procedures or otherwise as determined by plant management.

2-2 Management Policy and Direction.

2-2.1

Corporate management should establish a policy and institute a program to promote the conservation of property and continuity of operations as well as protection of safety to life by adequate fire prevention and fire protection measures at each facility.

2-2.2

Proper preventative maintenance of operating equipment as well as adequate operator training are important aspects of a viable fire prevention program.

2-3 Fire Risk Evaluation.

A Fire Risk Evaluation should be initiated as early in the design process as practical to ensure that the fire prevention and fire protection recommendations as described in this document have been evaluated in view of the plant-specific considerations regarding design, layout, and anticipated operating requirements. The evaluation should result in a list of recommended fire prevention features to be provided based on acceptable means for separation or control of common and special hazards, the control or elimination of ignition sources, and the suppression of fires.

2-4 Fire Prevention Program.

A written plant fire prevention program should be established and as a minimum should include the following:

(a) Fire safety information for all employees and contractors. This information should include, as a minimum, familiarization with fire prevention procedures, plant emergency alarms and procedures, and how to report a fire.

(b) Documented plant inspections including provisions for handling of remedial actions to correct conditions that increase fire hazards.

(c) A description of the general housekeeping practices and the control of transient combustibles. Fire experience has shown that transient combustibles can be a significant factor during a fire situation, especially during outages.

(d) Control of flammable and combustible liquids and gases in accordance with appropriate NFPA standards.

(e) Control of ignition sources to include smoking, grinding, welding, and cutting. (*See NFPA 51B, Standard for Fire Prevention in Use of Cutting and Welding Processes*.)

(f) Fire prevention surveillance. (*See NFPA 601, Standard for Security Services in Fire Loss Prevention.*)

(g) Fire report, including an investigation and a statement on the corrective action to be taken. (*See Appendix B.*)

2-5 Testing, Inspection, and Maintenance.

2-5.1

Upon installation, all fire protection systems should be preoperationally inspected and tested in accordance with applicable NFPA standards. Where appropriate standards do not exist, inspection and test procedures outlined in the purchase and design specifications should be followed.

2-5.2

All fire protection systems and equipment should be periodically inspected, tested, and maintained in accordance with applicable *National Fire Codes*®. (*See Table 2-5.2 for guidance.*)

NOTE: Inspection intervals for unattended plants may be permitted to be extended to normal plant inspections.

Table 2-5.2 Reference Guide for Fire Equipment Inspection, Testing, and Maintenance

Item	NFPA No.
Supervisory and Fire Alarm Circuits	72

Fire Detectors	72
Manual Fire Alarms	72
Sprinkler Water Flow Alarms	25/72
Sprinkler and Water Spray Systems	15/25
Foam Systems	11A/11C/16
Halogenated Agent, Chemical & Co. Systems	12/12A/17
Fire Pumps & Booster Pumps	20
Water Tanks & Alarms	25/22/72
P.I.V.s and O.S. & Y. Valves	25/72
Fire Hydrants and Associated Valves	25/24
Fire Hose and Standpipes	14/1962
Portable Fire Extinguishers & Hose Nozzles	10/1962
Fire Brigade Equipment	1971/1972/1973/1974
Fire Doors	80
Smoke Vents	204M
Emergency Lighting	70
Radio Communication Equipment	1221
Audible and Visual Signals	72

2-5.3

Testing, inspection, and maintenance should be documented with written procedures, results, and follow-up actions recorded.

2-6 Impairments.

2-6.1

A written procedure should be established to address impairments to fire protection systems and other plant systems that impact the level of fire hazard (e.g., dust collection systems, HVAC systems, etc.). As a minimum this procedure should:

(a) identify equipment not available for service;

(b) identify personnel to be notified (e.g., plant fire brigade chief, public fire department, etc.); and

(c) increase fire surveillance as needed. [*See 2-4(f).*]

2-6.2

Impairment to fire protection systems should be as short in duration as practical. If the impairment is planned, all necessary parts and manpower should be assembled prior to removing the protection system(s) from service. When an impairment is not planned, or when a system has discharged, the repair work or system restoration should be expedited.

2-6.3

Proper reinstallation after maintenance or repair should be performed to ensure proper systems operation. Once repairs are complete, tests that will ensure proper operation and restoration of full fire protection equipment capabilities should be made. Following restoration to service, the parties previously notified of the impairment should be advised. The latest revision of the design documents reflecting as-built conditions should be available to ensure that the system is properly reinstalled (e.g., drawings showing angles of nozzles).

2-7 Fire Emergency Plan.

2-7.1

A written fire emergency plan should be developed, and, as a minimum, this plan should include the following:

(a) response to fire alarms and fire systems supervisory alarms;

(b) notification of personnel identified in the plan;

(c) evacuation of employees not directly involved in fire-fighting activities from the fire area;

(d) coordination with security forces or other designated personnel to admit public fire department and control traffic and personnel;

(e) fire extinguishment activities;

(f) periodic drills to verify viability of the plan; and

(g) control room operator(s) activities during fire emergencies.

NOTE: Emergency conditions may warrant that breathing apparatus be readily available in the control room. Self-contained breathing apparatus should be considered for activities outside the control room.

2-7.2 Turbine Lubricating Oil Fires.

A critical aspect of responding to turbine lubricating oil fires is minimizing the size and duration of the oil spill. The need for lubrication to protect the turbine-generator bearings and shaft should be balanced against the fire damage from allowing the oil leak to continue. The following steps may be useful in minimizing fire damage and should be considered during preplanning and training for emergency conditions:

(a) tripping the turbine;

(b) breaking condenser vacuum;

(c) emergency purging of the generator; and

(d) shut down oil pumps.

These actions may cause significant mechanical damage to the turbine. The manufacturer should be consulted for additional guidance. (*See Appendix D.*)

2-8 Fire Brigade.

2-8.1

The size of the plant and its staff, the complexity of fire fighting problems, and the availability of a public fire department should determine the requirements for a fire brigade.

2-8.2*

If a fire brigade is provided, its organization and training should be identified in written procedures.

2-8.3

This section discusses special fire fighting conditions unique to fossil fueled steam electric generating plants. This information might be useful in fire brigade training and fire preplanning.

2-8.3.1 Regenerative Air Heaters. Since laboratory tests and reported incidents indicated a rapid increase in temperature to the 2800°F–3000°F (1537°C–1648°C) range in an air preheater fire, great care should be given to manual fire fighting. Large amounts of water will be needed to cool and extinguish a preheater fire. Fire preplanning should be accomplished to ensure use of an adequate number of access doors and safe access to the doors.

2-8.3.2 Electrostatic Precipitators. Once a fire is detected, the unit should go into emergency shutdown immediately. It should be recognized that during operation the atmosphere in the precipitator is oxygen-deficient and opening doors or running system fans following a fuel trip could cause conditions to worsen (increased potential for backdraft explosion). Once the flow of air and fuel to the fire has been stopped and the electrostatic precipitator has been shut down and deenergized, the precipitator doors may be permitted to be opened and water hoses employed if necessary.

2-8.3.3 Cable Trays. Cable tray fires should be handled like any fire involving energized electrical equipment. It may not be practical or desirable to deenergize the cables involved in the fire. Water is the most effective extinguishing agent for cable insulation fires but should be applied with an electrically safe nozzle. Some cables [polyvinyl chloride (PVC), Neoprene, or Hypalon] can produce dense smoke in a very short time. In addition, PVC liberates hydrogen chloride (HCl) gas. Self-contained breathing apparatus should be used by personnel attempting to extinguish cable tray fires.

2-8.3.4 Hydrogen System. Due to the wide explosive limits of hydrogen (4 percent to 75 percent volume of gas in air), under most conditions it is safer to allow a hydrogen fire to burn in a controlled manner until the gas can be shut off rather than to risk an explosion. It may be necessary to extinguish the fire in order to gain access to the shutoff valves.

2-8.3.5 Coal Storage and Handling.

2-8.3.5.1 Once the location and extent of a fire in a coal storage pile has been determined, the coal should be dug out and the heated coal removed. Since moisture accelerates oxidation, water used for fire fighting can aggravate the situation if the seat of the fire is not reached.

2-8.3.5.2 Clearly marked access panels in equipment should be provided for manual fire fighting. Coal dust presents both a fire and explosion hazard. Combustible, finely divided material is easily ignited. However, there is a possibility that a deep seated hard-to-extinguish fire can occur.

CAUTION: Application of an extinguishing agent that disturbs coal dust deposits could result in a dust explosion.

2-8.3.6 Coal Pulverizers. (*See NFPA 8502, Standard for the Prevention of Furnace Explosions/Implosions in Multiple Burner Boilers, and NFPA 8503, Standard for Pulverized Fuel Systems.*)

2-9 Identification of Fire Hazards of Materials.

Materials located in the plant or storage areas should be identified in accordance with NFPA 704, *Standard System for the Identification of the Fire Hazards of Materials*.

Chapter 3 General Plant Design

3-1 Plant Arrangement.

3-1.1 Fire Area Determination.

3-1.1.1 The electric generating plant and high voltage direct current converter station should be subdivided into separate fire areas as determined by the Fire Risk Evaluation for the purpose of limiting the spread of fire, protecting personnel, and limiting the resultant consequential damage to the plant. Fire areas should be separated from each other by fire barriers, spatial separation, or other approved means.

3-1.1.2 Determination of fire area boundaries should be based on consideration of the following:

(a) types, quantity, density, and locations of combustible material;

(b) location and configuration of plant equipment;

(c) consequence of losing plant equipment; and

(d) location of fire detection and suppression systems.

3-1.1.3 Unless consideration of the factors of 3-1.1.2 indicates otherwise, it is recommended that fire area boundaries be provided to separate the following:

(a) cable spreading room(s) and cable tunnel(s) from adjacent areas;

(b) control room, computer room, or combined control/computer room from adjacent areas;

NOTE: Where the control room and computer room are separated by a common wall, the wall need not have a fire resistance rating.

(c) rooms with major concentrations of electrical equipment, such as switchgear room and relay room, from adjacent areas;

(d) battery rooms from adjacent areas;

(e) maintenance shop(s) from adjacent areas;

(f) main fire pump(s) from reserve fire pump(s) where these pumps provide the only source of fire protection water;

(g) fire pumps from adjacent areas;

(h) warehouses from adjacent areas;

(i) emergency diesel generators from each other and from adjacent areas;

(j) fossil fuel-fired auxiliary boiler(s) from adjacent areas;

(k) fuel oil pumping, fuel oil heating facilities, or both, used for continuous firing of the boiler from adjacent areas;

(l) storage areas for flammable and combustible liquid tanks and containers from adjacent areas;

(m) office buildings from adjacent areas;

(n) telecommunication rooms from adjacent areas; and

(o) adjacent turbine generators beneath the underside of the operating floor.

3-1.1.4 Fire barriers separating fire areas should be a minimum of 2-hr fire resistance rating.

3-1.1.5 If a fire area is defined as a detached structure, it should be separated from other structures by an appropriate distance [e.g., 30 ft (9.1 m) minimum for a structure with moderate combustible loading and with a non-fire rated enclosure].

3-1.2 Openings in Fire Barriers.

3-1.2.1 All openings in fire barriers should be provided with fire door assemblies, fire dampers, penetration seals (fire stops), or other approved means having a fire protection rating consistent with the designated fire resistance rating of the barrier. Windows in fire barriers (e.g., control rooms or computer rooms) should be provided with a fire shutter or automatic water curtain. Penetration seals provided for electrical and piping openings should be listed or should meet the requirements for an "F" rating when tested in accordance with ASTM E 814, *Fire Tests of Through-Penetration Fire Stops*. Other test methods for qualifications of penetration seals, such as IEEE 634, *Testing of Fire Rated Penetration Seals*, may be permitted to be considered for this application.

NOTE 1: Listed penetration seals for large diameter piping may not be commercially available. In such instances the design should be similar to listed configurations.

NOTE 2: Listed penetration seals for the internals of non-segregated phase bus ducts and isolated phase bus ducts can be excluded.

3-1.2.2 Fire door assemblies, fire dampers, and fire shutters used in 2-hr rated fire barriers should be rated not less than $1^1/_2$ hr. (*See NFPA 80, Standard for Fire Doors and Fire Windows*.)

3-1.3 Hydrogen Storage.

Hydrogen storage facilities should be separated from adjacent areas. (*See NFPA 50A, Standard for Gaseous Hydrogen Systems at Consumer Sites, and NFPA 50B, Standard for Liquefied Hydrogen Systems at Consumer Sites*.)

3-1.4 Outdoor Oil-Insulated Transformers.

3-1.4.1 Outdoor oil-insulated transformers should be separated from adjacent structures and from each other by firewalls, spatial separation, or other approved means for the purpose of limiting the damage and potential spread of fire from a transformer failure.

3-1.4.2 Determination of the type of physical separation to be used should be based on consideration of the following:

(a) type and quantity of oil in the transformer;

(b) size of a postulated oil spill (surface area and depth);

(c) type of construction of adjacent structures;

(d) power rating of the transformer;

(e) fire suppression systems provided; and

(f) type of electrical protective relaying provided.

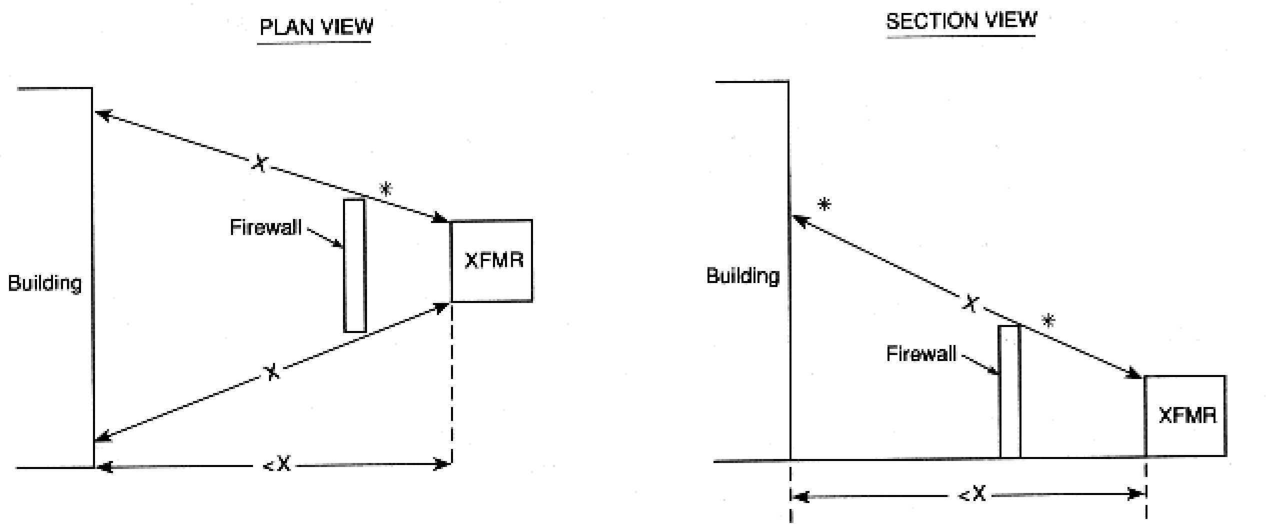
3-1.4.3 Unless consideration of the factors in 3-1.4.2 indicates otherwise, it is recommended that any oil-insulated transformer containing 500 gal (1893 L) or more of oil be separated from adjacent noncombustible or limited combustible structures by a 2-hr rated firewall or by spatial separation in accordance with Table 3-1.4.3. Where a firewall is provided between structures and a transformer, it should extend vertically and horizontally as indicated in Figure 3-1.4.3.

NOTE 1: As a minimum, the firewall should extend at least 1 ft (0.31 m) above the top of the transformer casing and oil conservator tank and at least 2 ft (0.61 m) beyond the width of the transformer and cooling radiators.

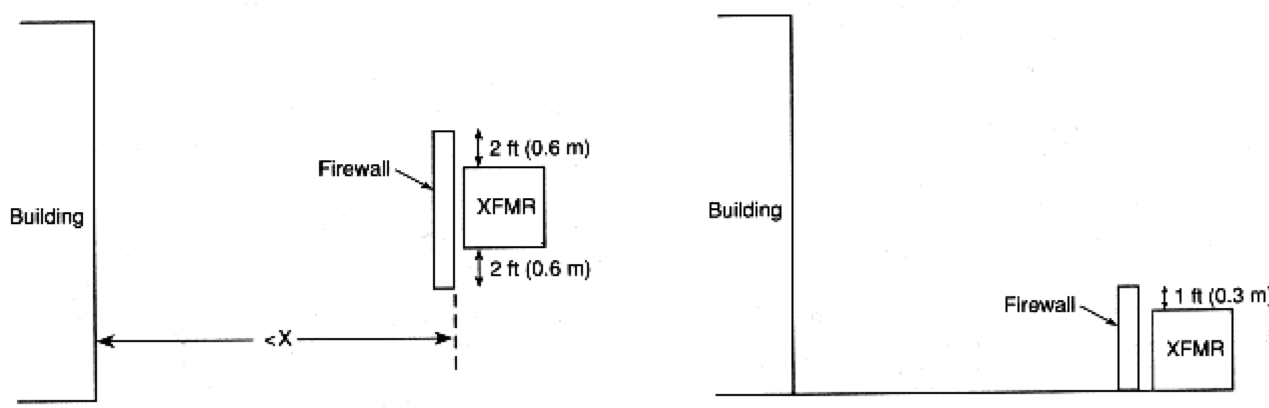
NOTE 2: If columns supporting the turbine building roof at the exterior wall have a 2-hr fire resistive rating above the operating floor, the firewall need not be higher than required to obtain line-of-sight protection to the height of the operating floor.

Table 3-1.4.3 Outdoor Oil Insulated Transformer Separation Criteria

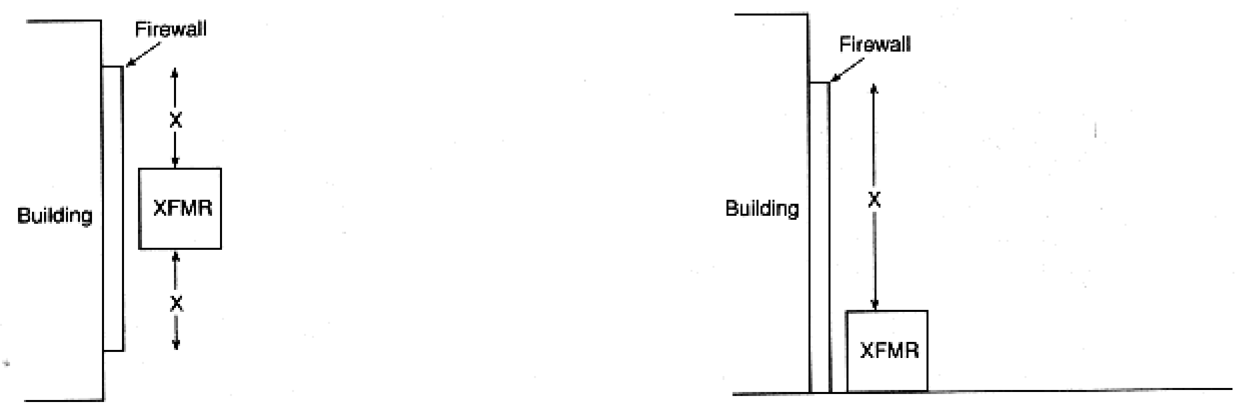
Transformer Oil Capacity	Minimum (Line-of-Sight) Separation without Firewall
Less than 500 gal (1893 L)	See 3-1.4.2
500 gal to 5000 gal (1893 L to 18,925 L)	25 ft (7.6 m)
Over 5000 gal (18,925 L)	50 ft (15 m)



Generic case



Example 1



Example 2

Figure 3-1.4.3 Outdoor oil-insulated transformer separation criteria.

3-1.4.4 Unless consideration of the factors in 3-1.4.2 indicates otherwise, it is recommended that adjacent oil-insulated transformers containing 500 gal (1893 L) or more of oil be separated from each other by a 2-hr rated firewall or by spatial separation in accordance with Table 3-1.4.3. Where a firewall is provided between transformers, it should extend at least 1 ft (0.31 m) above the top of the transformer casing and oil conservator tank and at least 2 ft (0.61 m) beyond the width of the transformer and cooling radiators.

3-1.4.5 Where a firewall is provided, it should be designed to withstand the effects of exploding transformer bushings or lightning arrestors.

NOTE: A higher noncombustible shield may be permitted to be provided to protect against the effects of an exploding transformer bushing.

3-1.4.6 Where a firewall is not provided, the edge of the postulated oil spill (i.e., containment basin, if provided) should be separated by a minimum of 5 ft (1.5 m) from the exposed structure to prevent direct flame impingement on the structure.

3-1.4.7 Outdoor transformers insulated with a less flammable liquid should be separated from each other and from adjacent structures that are critical to power generation by firewalls or spatial separation based on consideration of the factors in 3-1.4.2 and 3-1.4.5.

3-1.5 Indoor Transformers.

3-1.5.1 Dry-type transformers are preferred for indoor installations.

3-1.5.2 Oil-insulated transformers of greater than 100 gal (379 L) oil capacity installed indoors should be separated from adjacent areas by fire barriers of 3-hr fire resistance rating.

NOTE: Where multiple transformers of less than 100 gal (379 L) capacity each are located within close proximity, additional fire protection may be required based on the Fire Risk Evaluation.

3-1.5.3 Transformers having a rating greater than 35 kV, insulated with a less flammable liquid or nonflammable fluid and installed indoors should be separated from adjacent areas by fire barriers of 3-hr fire resistance rating.

3-1.5.4 Where transformers are protected by an automatic fire suppression system, the fire barrier fire resistance rating may be permitted to be reduced to 1 hr.

3-2 Life Safety.

3-2.1

For life safety for electric generating plants included in the scope of this document, see NFPA *101*®, *Life Safety Code*®.

3-2.2

Structures should be classified as follows, as defined in NFPA *101*, *Life Safety Code*:

(a) General areas should be considered as special purpose industrial occupancies.

NOTE 1: It generally is recognized that boiler and turbine buildings, protected in accordance with this document, meet the intent of NFPA *101*, *Life Safety Code*, for additional travel distances for fully sprinklered facilities.

NOTE 2: NFPA *101* allows additional means of egress components for special purpose industrial occupancies.

These areas may be permitted to be provided with fixed industrial stairs, fixed ladders (*see ANSI A1264.1, Safety Requirements for Workplace Floor and Well Openings, Stairs, and Railing Systems and* ANSI A14.3, *Standard for Safety Requirements for Fixed Ladders*), or alternating tread devices (*see NFPA 101*). Examples of these spaces include catwalks, floor areas, or elevated platforms that are provided for maintenance and inspection of in-place equipment.

NOTE 3: Spaces internal to equipment and machinery are excluded from the requirements of NFPA *101*. Examples of these spaces include, but are not limited to, the internals of the following:

1. boilers;
2. scrubbers;
3. pulverizers;
4. combustion turbine enclosures;
5. cooling towers;
6. bunkers, silos, and hoppers;
7. conveyor pulley take-up areas; or
8. electrostatic precipitators.

(b) Open structures and underground structures (e.g., tunnels) should be considered as occupancies in special structures.

(c) General office structures should be considered as business occupancies.

(d) Warehouses should be considered as storage occupancies.

(e) Coal preparation and handling facilities (e.g., enclosed crusher houses, transfer houses, and conveyors) should be considered special purpose industrial occupancies.

(f) Scrubber buildings should be considered as special purpose industrial occupancies.

3-2.3

In the event of a plant fire, egress of occupants in control facilities may be delayed due to emergency shutdown procedures. Control facilities should have a means of egress that is separated from other plant areas to facilitate a delayed egress.

3-3 Building Construction Materials.

3-3.1

Construction materials being considered for electric generating plants and high voltage direct current converter stations should be selected based on the Fire Risk Evaluation and on consideration of the following NFPA standards:

(a) NFPA 220, *Standard on Types of Building Construction*;

(b) NFPA 251, *Standard Methods of Tests of Fire Endurance of Building Construction and Materials*;

(c) NFPA 253, *Standard Method of Test for Critical Radiant Flux of Floor Covering Systems Using a Radiant Heat Energy Source*;

(d) NFPA 255, *Standard Method of Test of Surface Burning Characteristics of Building Materials*;

(e) NFPA 259, *Standard Test Method for Potential Heat of Building Materials*.

3-3.2

Construction materials used in the boiler, engine, or turbine-generator buildings or other buildings critical to power generation or conversion should meet the definition of noncombustible or limited combustible, except roof coverings, which should be as outlined in 3-3.3, and except for limited use of translucent reinforced plastic panels as allowed by the Fire Risk Evaluation.

3-3.3

Roof covering should be Class A in accordance with NFPA 256, *Standard Methods of Fire Tests of Roof Coverings*. Metal roof deck construction, where used, should be “Class I” or “fire classified.”

3-3.4 Interior Finish.

3-3.4.1 Cellular or foamed plastic materials (as defined in Appendix A of NFPA *101*, *Life Safety Code*) should not be used as interior finish.

3-3.4.2 Interior finish in buildings critical to power generation or conversion should be Class A.

3-3.4.3 Interior finish in buildings not critical to power generation or conversion should be Class A or Class B.

3-4 Smoke and Heat Venting, Heating, Ventilating, and Air Conditioning.

3-4.1 Smoke and Heat Venting.

3-4.1.1 General. Smoke and heat vents are not substitutes for normal ventilation systems unless designed for dual usage, and should not be used to assist such systems for comfort ventilation. Smoke and heat vents should not be left open where they can sustain damage from high wind conditions. They should be included in surveillance programs to ensure availability in emergency situations.

3-4.1.2 Heat Vents.

3-4.1.2.1 Heat vents should be provided for areas identified by the Fire Risk Evaluation. Where heat vents are provided, heat generated under fire conditions should be vented from its place of origin directly to the outdoors.

3-4.1.2.2 Heat vents in the boiler and turbine building may be permitted to be provided through the use of automatic heat vents or windows at the roof eave line. Heat venting in areas of high combustible loading can reduce damage to structural components. (*See NFPA 204M, Guide for Smoke and Heat Venting.*)

3-4.1.3 Smoke Vents.

3-4.1.3.1 Smoke venting should be provided for areas identified by the Fire Risk Evaluation. Where smoke venting is provided, smoke should be vented from its place of origin in a manner that does not interfere with the operation of the plant.

3-4.1.3.2 Separate smoke ventilation systems are preferred; however, smoke venting can be integrated into normal ventilation systems using automatic or manually positioned dampers and motor speed control. (*See NFPA 90A, Standard for the Installation of Air Conditioning and Ventilating Systems; NFPA 92A, Recommended Practice for Smoke-Control Systems; and NFPA 204M, Guide for Smoke and Heat Venting.*) Smoke venting also may be permitted to be accomplished through the use of portable smoke ejectors.

3-4.1.3.3 Consideration should be given to smoke venting for the following areas: control room, cable spreading room(s), and switchgear room.

3-4.1.3.4 In the areas with gaseous fire extinguishing systems, the smoke ventilation system should be properly interlocked to ensure the effective operation of the gaseous fire extinguishing system.

3-4.1.3.5 Smoke removal system dampers, where installed, normally are operable only from an area immediately outside of, or immediately within, the fire area served since it is desired to have entry into, and inspection of, the fire area by fire-fighting personnel prior to restoring mechanical ventilation to the fire area. Smoke removal system dampers may be permitted to be operable from the control room if provisions are made to prevent premature operation. This can be accomplished using thermal interlocks or administrative controls.

3-4.1.3.6 The fan power supply wiring and controls for smoke exhaust should be located external to the fire area served by the fan or be installed in accordance with the Fire Risk Evaluation.

3-4.2 Normal Heating, Ventilating, and Air Conditioning Systems.

3-4.2.1 For normal heating, ventilating, and air conditioning systems, see NFPA 90A, *Standard for the Installation of Air Conditioning and Ventilating Systems*, or NFPA 90B, *Standard for the Installation of Warm Air Heating and Air Conditioning Systems*, as appropriate.

3-4.2.2 Air conditioning for the control room should provide a pressurized environment to preclude the entry of smoke in the event of a fire outside the control room.

3-4.2.3 Plastic ducts, including listed fire-retardant types, should not be used for ventilating systems. Listed plastic fire-retardant ducts with appropriate fire protection may be permitted to be used in areas with corrosive atmospheres.

3-4.2.4 Fire dampers (doors) compatible with the rating of the barrier should be provided at the duct penetrations to the fire area (*see Section 3-1*) unless the duct is protected throughout its length by a fire barrier equal to the rating required of fire barrier(s) penetrated.

3-4.2.5 Smoke dampers, where installed, should be installed in accordance with NFPA 90A, *Standard for the Installation of Air Conditioning and Ventilating Systems*.

3-4.2.6 The fresh air supply intakes to all areas should either be located so as to minimize the possibility of drawing products of combustion into the plant, or be provided with automatic closure on detection of smoke. Separation from exhaust air outlets, smoke vents from other areas, and outdoor fire hazards should all be considered.

3-5 Drainage.

3-5.1

Provisions should be made in all fire areas of the plant for removal of all liquids directly to safe areas or for containment in the fire area without flooding of equipment and without endangering other areas. (*See Appendix A of NFPA 15, Standard for Water Spray Fixed Systems for Fire Protection.*) Drainage and prevention of equipment flooding should be accomplished by one or more of the following:

(a) floor drains;

(b) floor trenches;

(c) open doorways or other wall openings;

(d) curbs for containing or directing drainage;

(e) equipment pedestals;

(f) pits, sumps, and sump pumps.

3-5.2

The provisions for drainage and any associated drainage facilities should be sized to accommodate all of the following:

(a) The spill of the largest single container of any flammable or combustible liquids in the area.

(b) The maximum expected number of fire hose lines [500 gpm (31.5 L/sec) minimum] operating for a minimum of 10 minutes.

(c) The maximum design discharge of fixed fire suppression systems operating for a minimum of 10 minutes.

NOTE: Design discharge for the turbine building should be based on the expected time necessary to take the turbine off line and put it on turning gear, but not less than 10 minutes.

3-5.3

The drainage system for continuous fuel oil-fired boilers should consist of curbs and gutters arranged to confine the area of potential fuel oil discharge. Consideration also should be given to providing the same measures for coal-fired boilers using oil for ignition. Walking surfaces in the vicinity of burners should be made impervious to oil leakage by the use of checkered steel plate, sheet metal drip pans, or other means. Curbs in passageways should have ramps or steps or be otherwise constructed to present no obstacle to foot traffic. Gutter outlet pipes and all other drains should be trapped to prevent the passage of flames and permit the flow of oil. A clearance between the boiler front and the walk structure is required for the differential movement where the heated boiler elongates. This clearance space in the vicinity of the burners should be flashed and counter-flashed with sheet metal or otherwise arranged to allow movement and to redirect dripping oil, which may impinge on the boiler face.

3-5.4

Floor drainage from areas containing flammable or combustible liquids should be trapped to prevent the spread of burning liquids beyond the fire area.

3-5.5

Where gaseous fire suppression systems are installed, floor drains should be provided with adequate seals or the fire suppression system should be sized to compensate for the loss of fire suppression agent through the drains.

3-5.6

Drainage facilities should be provided for outdoor oil-insulated transformers, or the ground should be sloped such that oil spills will flow away from buildings, structures, and adjacent transformers. Unless drainage from oil spills is accommodated by sloping the ground around transformers away from structures or adjacent equipment, consideration should be given to providing curbed areas or pits around transformers. The pit or drain system or both should be sized in accordance with 3-5.2. If a layer of uniformly graded stone is provided in the bottom of the curbed area or pit as a means of minimizing ground fires, the following should be addressed:

(a) Sizing of the pit should allow for the volume of the stone.

(b) The design should address the possible accumulation of sediment or fines in the stone.

3-5.7

For facilities consisting of more than one generating unit that are not separated by a fire barrier [*see 3-1.1.3(o)*], provisions such as a sloped floor, curb, or trench drain should be provided on solid floors where the potential exists for an oil spill, such that oil released from an incident in one unit will not expose an adjacent unit.

3-5.8

For environmental reasons, liquid discharges resulting from oil spills or operation of a fire suppression system may have to be treated (e.g., oil separation).

3-6 Emergency Lighting.

3-6.1

Emergency lighting should be provided for means of egress. (*See NFPA 101*, *Life Safety Code*.)

3-6.2

Emergency lighting should be provided for critical plant operations areas.

3-7 Lightning Protection.

Lightning protection should be provided for those structures having a risk index (R) of four or greater when evaluated in accordance with NFPA 780, *Standard for the Installation of Lightning Protection Systems*.

Chapter 4 General Fire Protection Systems and Equipment

4-1 General.

All fire protection systems, equipment, and installations should be dedicated to fire protection purposes.

4-2 Water Supply.

4-2.1

The water supply for the permanent fire protection installation should be based on providing a

2-hr supply for both items (a) and (b) as follows:

(a) Either of items 1 or 2 below, whichever is larger:

1. The largest fixed fire suppression system demand,

2. Any fixed fire suppression system demands that could reasonably be expected to operate simultaneously during a single event [e.g., turbine under floor protection in conjunction with other fire protection system(s) in the turbine area; coal conveyor protection in conjunction with protection for related coal handling structures during a conveyor fire; adjacent transformers not adequately separated according to 3-1.3].

(b) The hose stream demand of not less than 500 gpm (31.5 L/sec).

4-2.2

Where an adequate and reliable water supply, such as a lake, cooling pond, river, or municipal water system, is unavailable, at least two separate water supplies should be provided for fire protection purposes with each supply capable of meeting the fire water flow requirements determined by 4-2.1.

4-2.3

Each water supply should be connected to the yard main by separate connections arranged and valve controlled to minimize the possibility of multiple supplies being impaired simultaneously.

4-2.4

In some rivers and tributaries the existence of microorganisms limits the use of raw water for fire protection without treatment. Consideration of water quality may prevent long-term problems relating to fire protection water supply.

4-2.5 Fire Pumps.

4-2.5.1 Where multiple fire pumps are required, the pumps should not be subject to a common failure, electrical or mechanical, and should be of sufficient capacity to meet the fire flow requirements determined by 4-2.1 with the largest pump out of service.

4-2.5.2 Fire pumps should be automatic starting with manual shutdown. The manual shutdown should be at the pump controllers only. (*See NFPA 20, Standard for the Installation of Centrifugal Fire Pumps.*)

4-2.6 Water Supply Tanks.

4-2.6.1 If tanks are of dual-purpose use, a standpipe or similar arrangement should be provided to dedicate the amount determined by 4-2.1 for fire protection use only. (*See NFPA 22, Standard for Water Tanks for Private Fire Protection.*)

4-2.6.2 Where tanks are used, they should be filled from a source capable of replenishing the two-hour supply for the fire protection requirement in an eight-hour period. The eight-hour (time) requirement for refilling may be permitted to be extended if the initial supply exceeds the minimum storage requirement on a volume per time ratio basis. It normally is preferred for the refilling operation to be accomplished on an automatic basis.

4-3 Valve Supervision.

All fire protection water supply and system control valves should be under a periodic inspection program (*see Chapter 2*) and should be supervised by one of the following methods:

(a) Electrical supervision with audible and visual signals in the main control room or another constantly attended location.

(b) Locking valves open. Keys should be made available only to authorized personnel.

(c) Sealing of valves. This option should be followed only where valves are within fenced enclosures under the control of the property owner.

4-4 Yard Mains, Hydrants, and Building Standpipes.

4-4.1 Yard Mains and Hydrants.

4-4.1.1 Yard mains and outdoor fire hydrants should be installed on the plant site. (*See NFPA 24, Standard for the Installation of Private Fire Service Mains and Their Appurtenances.*)

4-4.1.2 Remotely located plant-related facilities should be reviewed on an individual basis to determine the need for fire protection. If excessively long extensions of underground fire mains are necessary for fire protection at these locations, it may be permitted to supply this need from an available service main in the immediate area. Where common supply piping is provided for service water and fire protection water supply, it should be sized to accommodate both service water and fire protection demands.

4-4.1.3 The supply mains should be looped around the main power block and should be of sufficient size to supply the flow requirements determined by 4-2.1 to any point in the yard loop considering the most direct path to be out of service. Pipe sizes should be designed to encompass any anticipated expansion and future water demands.

4-4.1.4 Indicator control valves should be installed to provide adequate sectional control of the fire main loop to minimize plant protection impairments.

4-4.1.5 Each hydrant should be equipped with a separate shutoff valve located on the branch connection to the supply main.

4-4.1.6 Interior fire protection loops are considered an extension of the yard main and should be provided with at least two valved connections to the yard main with appropriate sectional control valves on the interior loop.

4-4.2 Standpipe and Hose Systems.

4-4.2.1 Standpipe and hose systems should be installed. (*See NFPA 14, Standard for the Installation of Standpipe and Hose Systems.*) The standpipe and hose system is an extension of the yard fire main and hydrant system. The hose stations should be capable of delivering the hose stream demand for the various hazards in buildings.

4-4.2.2 Fire main connections for standpipes should be arranged so that a fire main break can be isolated without interrupting service simultaneously to both fixed protection and hose connections protecting the same hazard or area. Choice of Class I, Class II, or Class III systems should be made by a Fire Risk Evaluation. (*See NFPA 14, Standard for the Installation of Standpipe and Hose Systems.*)

4-4.2.3 The standpipe piping should be capable of providing minimum volume and pressure for the highest hose stations.

4-4.2.4 Due to the open arrangement of these plants, the locations of hose stations should take into account safe egress for personnel operating hose lines.

4-4.3 Hose Nozzles.

Spray nozzles having shutoff capability and listed for use on electrical equipment should be provided on hoses located in areas near energized electrical equipment.

4-4.4 Hose Threads.

Hose threads on hydrants and standpipe systems should be compatible with fire hose used by the responding fire departments.

4-5 Portable Fire Extinguishers.

Portable fire extinguishers should be provided. (*See NFPA 10, Standard for Portable Fire Extinguishers.*)

4-6 Fire Suppression Systems and Equipment — General Requirements.

4-6.1

Fire suppression systems and equipment should be provided in all areas of the plant as identified in Chapters 5, 6, 7, and 8 or as determined by the Fire Risk Evaluation. Fixed suppression systems should be designed in accordance with the following codes and standards unless specifically noted otherwise:

NFPA 11, *Standard for Low-Expansion Foam*

NFPA 11A, *Standard for Medium- and High-Expansion Foam Systems*

NFPA 12, *Standard on Carbon Dioxide Extinguishing Systems*

NFPA 12A, *Standard on Halon 1301 Fire Extinguishing Systems*

NFPA 13, *Standard for the Installation of Sprinkler Systems*

NFPA 15, *Standard for Water Spray Fixed Systems for Fire Protection*

NFPA 16, *Standard for the Installation of Deluge Foam-Water Sprinkler and Foam-Water Spray Systems*

NFPA 17, *Standard for Dry Chemical Extinguishing Systems*

NFPA 231, *Standard for General Storage*

NFPA 231C, *Standard for Rack Storage of Materials.*

4-6.2

The selection of an extinguishing agent or a combination of extinguishing agents should be based on:

(a) The type of hazard;

(b) The effect of agent discharge on equipment;

(c) The health hazards.

4-6.3 Fire Suppression System Safety Considerations.

4-6.3.1 It is imperative that safety in the use of any fire suppression system be given proper consideration and that adequate planning be done to ensure safety of personnel.

4-6.3.2 Potential safety hazards could include impingement of high velocity discharge on personnel, loss of visibility, hearing impairment, reduced oxygen levels that will not support breathing, toxic effects of the extinguishing agent, breakdown products of the extinguishing agent, and electric conductivity of water-based agents.

4-6.3.3 When working in areas (e.g., combustion turbine compartments) where egress is difficult, the fire extinguishing system should be provided with an isolation (inhibit) switch to prevent discharge of the system. A trouble indication should be provided when the system is in the "inhibit" mode.

4-6.3.4 NFPA standards for the extinguishing systems used should be carefully studied and the personnel safety provisions followed. Evacuation of a protected area is recommended before any special extinguishing system discharges. Alarm systems that are audible above machinery background noise, or that are visual or olfactory or a combination, should be used where appropriate. Personnel warning signs are necessary.

4-7 Fire-Signaling Systems.

4-7.1

The type of protective signaling system for each installation and area should be determined by the Fire Risk Evaluation in consideration of hazards, arrangement, and fire suppression systems. Fire detection and automatic fixed fire suppression systems should be equipped with local audible and visual signals with annunciation in a constantly attended location, such as the main control room. Audible fire alarms should be distinctive from other plant system alarms. See NFPA 72, *National Fire Alarm Code*.

4-7.2

Automatic fire detectors should be installed in accordance with NFPA 72, *National Fire Alarm Code*.

4-7.3

The fire-signaling system or plant communication system should provide the following:

(a) Manual fire alarm devices (e.g., pull boxes or page party stations) installed in all occupied buildings. Manual fire alarm devices should be installed for remote yard hazards as identified by the Fire Risk Evaluation.

(b) Plant-wide audible fire alarm or voice communication systems, or both, for purposes of personnel evacuation and alerting of plant emergency organization. The plant public address system, if provided, should be available on a priority basis.

(c) Two-way communications for the plant emergency organization during emergency operations.

(d) Means to notify the public fire department.

Chapter 5 Identification of and Protection against Hazards

5-1 General.

The identification and selection of fire protection systems should be based on the Fire Risk

Evaluation. This chapter identifies fire and explosion hazards in fossil fueled electric generating stations and specifies the recommended protection criteria unless the Fire Risk Evaluation indicates otherwise.

5-2 Fuel Handling — Gas.

5-2.1

The storage and associated piping systems for gases in the gaseous or liquefied states should comply with NFPA 54, *National Fuel Gas Code*; NFPA 58, *Standard for the Storage and Handling of Liquefied Petroleum Gases*; and ANSI B31.1, *Code for Power Piping*.

5-2.2

The plant's main and ignitor natural gas shut-off valve should be located near an exterior wall. The valve should be provided with both manual and automatic closing capabilities locally, and remote closing capability from the control room. The valve should be arranged to fail closed on the loss of power or pneumatic control.

5-2.3

Electrical equipment in areas with potentially hazardous atmospheres should be designed and installed in compliance with Articles 500 and 501 of NFPA 70, *National Electrical Code®*, and ANSI C2, *National Electrical Safety Code*.

5-3 Fuel Handling — Oil.

5-3.1

Fuel oil storage, pumping facilities, and associated piping should comply with NFPA 30, *Flammable and Combustible Liquids Code*; NFPA 31, *Standard for the Installation of Oil-Burning Equipment*; and ANSI B31.1, *Code for Power Piping*.

5-3.2

Internal tank heaters needed to maintain oil pumpability should be equipped with temperature sensing devices that alarm in a constantly attended area prior to the overheating of the oil.

5-3.3

External tank heaters should be interlocked with a flow switch to shut off the heater if oil flow is interrupted.

5-3.4

Tank filling operations should be monitored to prevent overfilling.

5-3.5

While oil unloading operations are in progress, the unloading area should be manned by personnel properly trained in the operation of pumping equipment, valving, and fire safety.

5-3.6

Pump installations should not be located within tank dikes.

5-3.7

Electrical equipment in areas with potentially hazardous atmospheres should be designed and installed in compliance with NFPA 30, *Flammable and Combustible Liquids Code*; Articles 500 and 501 of NFPA 70, *National Electrical Code*; and ANSI C2, *National Electrical Safety Code*.

5-3.8

To prevent hazardous accumulations of flammable vapors, ventilation for indoor pumping facilities for flammable liquids should provide at least 1 ft^3 of exhaust air per ft^2 of floor area (0.30 m^3/m^2), but not less than 150 ft^3/min (0.071 m^3/sec).

5-3.9 Fire Protection.

5-3.9.1 Indoor fuel oil pumping or heating facilities or both should be protected with automatic sprinklers, water spray, foam-water sprinklers, or gaseous total flooding system(s). Local application dry chemical systems may be permitted to be used in areas that normally do not have re-ignition sources, such as steam lines or hot boiler surfaces.

5-3.9.2 The provision of foam systems for tank protection should be considered in the Fire Risk Evaluation with consideration of exposure to other important structures, product value, and resupply capability.

5-3.9.3 Fuel oil handling and storage areas should be provided with hydrant protection in accordance with Section 4-4.

5-4 Fuel Handling — Coal.

5-4.1 Storage.

5-4.1.1 Coal storage piles are subject to fires caused by spontaneous heating of the coal. The coals most susceptible to self-heating are those with high pyritic content and high intrinsic moisture and oxygen content, such as low-rank coals. The mixing of high pyritic coals with high moisture and oxygen coals increases self-heating.

5-4.1.2 There are measures that can be taken to lessen the likelihood of coal pile fires. These measures are dependent on the type and rank of coal. Among the more important are:

(a) Short duration, active, or "live" storage piles should be worked to prevent dead pockets of coal, a potential source of spontaneous heating.

(b) Coal piles should not be located above sources of heat, such as steam lines, or sources of air, such as manholes.

(c) Coal placed in long-term storage should be piled in layers, appropriately spread, and compacted prior to the addition of subsequent layers to reduce air movement and to minimize water infiltration into the pile.

(d) Different types of coal that are not chemically compatible should not be stored in long-term storage piles.

(e) Access to coal storage piles should be provided for fire fighting operations and for pulling out hot pockets of coal.

5-4.2 Bins, Bunkers, and Silos.

The recommendations of this section should be considered to reduce the probability of serious fire. (*See NFPA 8503, Standard for Pulverized Fuel Systems.*)

5-4.2.1* Storage structures should be of noncombustible construction and designed to minimize corners or pockets that cause coal to remain trapped and present a potential for spontaneous combustion.

5-4.2.2* During planned outages, coal bins, bunkers, or silos should be emptied to the extent practical.

5-4.2.3* The period of shutdown requiring emptying of the bins depends on the spontaneous heating characteristics of the coal. However, spontaneous heating can be slowed by minimizing air flow through the bins by such means as inerting or filling the bins with high-expansion foam.

5-4.2.4 During idle periods, flammable gas monitors can be installed at the top of the silo to monitor methane gas and carbon monoxide concentrations. Flammable gas monitors should be arranged to alert plant operators if methane concentrations are detected or carbon monoxide concentration exceeds 1.25 percent concentration by volume. Heat detectors can also be inserted to detect temperature increase due to spontaneous combustion.

5-4.2.5 Once spontaneous heating develops to the fire stage, it becomes very difficult to extinguish the fire short of emptying the bin, bunker, or silo. Therefore, provisions for emptying the bunker should be provided. This might take the form of conveyors discharging to a stacking out pile. Another method would use flanged openings for removing the coal if adequate planning and necessary equipment have been provided. Removing hot or burning coal can lead to a dust explosion if a dust cloud develops. Therefore, means should be provided to prevent a dust cloud, such as covering the coal with a blanket of high-expansion foam.

5-4.2.6* If fire occurs in a silo it is necessary to initiate manual actions for suppression and extinguishment. The following fire fighting strategies have been successfully employed (depending on the specific circumstances and type of coal used):

(a) Use of Class A foams and penetrants;

(b) Injection of inert gas (i.e., carbon dioxide or nitrogen);

(c) Emptying the silo through the feeder pipe to a safe location (inside or outside the powerhouse), and trucking away the debris.

NOTE: All signs of spontaneous combustion and fire must be eliminated prior to the movement of coal.

CAUTION:

1. Water has been successfully used to control bunker and silo fires. However, the possibility of an explosion exists under certain circumstances if the water reaches the coal in a hot spot. Therefore, water is not a recommended fire fighting strategy for these types of fire events. The amount of water delivered to a silo in a stream can create structural support problems.

2. Steam-smothering has also been used to control bunker and silo fires on marine vessels. All openings need to be sealed prior to the introduction of steam. This is rarely possible at electric generating plants due to the relatively porous nature of the equipment.

The use of steam introduces high temperature and moisture that could increase the possibility of spontaneous combustion; therefore, this strategy is not recommended.

3. Locating silo hot spots and extinguishing them before the coal leaves the silo is an accepted practice. The coal hot spots are detected and extinguished. If, as the coal drops down through the silo, additional hot spots are detected, coal flow should be stopped and the hot spots extinguished. If the hot spots are exposed during the lowering of the coal, potential for dust

explosions is increased.

5-4.2.7 Care should be taken where working in enclosed areas near coal bins, bunkers, or silos in confined areas since spontaneous heating of coal can generate gases that are both toxic and explosive. Fixed or portable carbon monoxide monitoring should be provided to detect spontaneous heating and hazardous conditions.

5-4.2.8 Dusttight barriers should be provided between the boiler house and the areas of the coal handling system above the bin, bunker, or silo.

5-4.3* Dust Suppression and Control.

5-4.3.1 Coal dust generated due to coal handling constitutes a fire and explosion hazard that should be controlled by one or more of the following methods:

(a) a dust collection system;

(b) a dust suppression system;

(c) an open-air construction.

5-4.3.2 Where dust collection or suppression systems are installed to prevent hazardous dust concentration, appropriate electrical and mechanical interlocks should be provided to prevent the operation of coal handling systems prior to the starting and sustained operation of the dust control equipment.

NOTE: Constructing enclosure hoods at transfer points can minimize the amount of dust released to surrounding areas, which can reduce the need for dust collection.

5-4.3.3 Dust suppression systems usually consist of spray systems using water or surfactants, or both, to reduce the dust generation of coal handling operations. The sprays are normally applied at or near those locations where the coal is transferred from one conveyor to another.

5-4.3.4 For dust collection systems provided for handling combustible dusts, see NFPA 91, *Standard for Exhaust Systems for Air Conveying of Materials*. Other recommendations for reducing the probability of explosion and fire from coal dust are:

(a) Fans for dust collectors should be installed downstream of the collectors so that they handle only clean air.

(b) For dust collectors vented to the outside, see NFPA 68, *Guide for Venting of Deflagrations*. Explosion suppression systems may be permitted to be provided for dust collection systems that cannot be safely vented to the outside. (*See NFPA 69, Standard on Explosion Prevention Systems.*)

(c) Dust collection hoppers should be emptied prior to shutting down dust removal systems to reduce the likelihood of collector fires originating from spontaneous heating in the dust hopper.

(d) High level detection with an annunciator alarm should be provided for the dust hoppers.

5-4.3.5 Cleaning methods such as vigorous sweeping of dust or blowing down with steam or compressed air should not be used since these methods can produce an explosive atmosphere. Preferred cleaning methods would use appropriate portable or fixed pipe vacuum cleaners of a type approved for dust hazardous locations or low velocity water spray nozzles and hose.

5-4.4 Coal Conveyors.

5-4.4.1 Coal conveyor belts should be of material designed to resist ignition. U.S. Mine Safety and Health Administration and Canadian Bureau of Mines Standards for fire retardant conveyor belt materials should be used as a guide. However, “fire retardant” belt materials will burn and therefore may require additional fire protection.

5-4.4.2 Each conveyor system should be arranged to automatically shut off driving power in the event of belt slowdown of greater than 20 percent or misalignment of belts. In addition, a complete belt interlock shutdown system should be provided so that, if any conveyor stops, the power to all conveyor systems feeding that belt would be shut down automatically.

5-4.4.3 Hydraulic systems should use only listed fire retardant hydraulic fluids. Where unlisted hydraulic fluids must be used, consideration should be given to protection by a fire suppression system.

5-4.4.4 Foreign materials pose a threat to crushers, pulverizers, and feeders by interrupting the flow of coal or by causing sparks capable of igniting coal dust/air mixtures. Methods of removing tramp metals and other foreign materials include magnetic separators, pneumatic separators, and screens. Means for removing such foreign material should be provided as early in the coal handling process as possible.

5-4.5 Coal Conveying and Handling Structures.

5-4.5.1 Coal conveying and handling structures and supports should be of noncombustible construction.

5-4.5.2 The accumulation of coal dust in enclosed buildings can be reduced by designing structural members such that their shape or method of installation minimizes the surface area where dust can settle. Consideration should be given to installing structural members exterior to the enclosure. Access should be provided to facilitate cleaning of all areas.

5-4.5.3 For explosion venting for enclosed structures, see NFPA 68, *Guide for Venting of Deflagrations*.

5-4.5.4 Provisions should be made for deenergizing both lighting and electrical power circuits without requiring personnel to enter dust-producing sections of the plant during emergencies.

5-4.5.5 Areas of the coal handling system requiring heat should use approved heaters suitable for hazardous areas. The heating equipment should be kept free of dusts and should be designed to limit surface temperature to 329°F (165°C).

5-4.5.6 Electrical equipment within coal handling areas should be approved for use in hazardous locations Class II, Division 1 or Division 2, Group F. Electrical equipment subject to accumulations of methane gas or carbon monoxide should also be listed and installed, as appropriate, for use in hazardous locations Class I, Division 2, Group D. (*See Articles 500 and 501 of NFPA 70, National Electrical Code, and Section 127 of ANSI C2, National Electrical Safety Code*.)

5-4.5.7 Static electricity hazards should be minimized by the permanent bonding and grounding of all equipment, including duct work, conveyor drive belts, pulleys, idlers, take-up reels, motor drives, dust collection equipment, and vacuum cleaning equipment. (*See NFPA 77, Recommended Practice on Static Electricity*.)

5-4.6 Fire Protection.

5-4.6.1 Automatic sprinkler or water spray systems should be provided for coal handling structures that are critical to power generation and subject to accumulations of coal or coal dust. Sprinkler systems should be designed for a minimum of 0.25 gpm/ft^2 (0.17 $L/sec\text{-}m^2$) density over a 2500 ft^2 (232 m^2) area. If water spray systems are used to protect structures, the same densities should be used.

5-4.6.2 Automatic water spray or sprinkler systems should be provided for enclosed coal conveyors that are critical to continuous power generation. Sprinklers should be designed for a minimum of 0.25 gpm/ft^2 (0.17 $L/sec\text{-}m^2$) density over 2000 ft^2 (186 m^2) of enclosed area or the most remote 100 linear ft (30 m) of conveyor structure up to 2000 ft^2 (186 m^2). For water spray design criteria, see NFPA 15, *Standard for Water Spray Fixed Systems for Fire Protection*.

5-4.6.2.1 If a sprinkler system is used to protect the coal conveyor, particular care should be exercised in locating closed sprinkler heads so that they will be in the path of the heat produced by the fire and still be in a position to provide good coverage of all belt surfaces along the conveyor.

5-4.6.2.2 Conveyors that are below grade or enclosed are extremely hazardous to maintenance or fire fighting personnel in the event of a fire. Automatic water spray or sprinkler systems should be provided for these conveyors even though they may not be critical to plant operations.

5-4.6.2.3 Actuation of water spray or sprinkler systems should shut down the conveyor belt involved and all conveyor belts feeding the involved belt.

5-4.6.2.4 Dust collectors and fans should automatically shut down along with other related equipment upon detection of fire.

5-4.6.2.5 Draft barriers installed at the end and mid-points of enclosed conveyors should be considered in the Fire Risk Evaluation. Draft barriers will reduce the response time of installed automatic sprinkler or detection systems and minimize the chimney effects in the event of fire.

5-4.6.3 Stacker-reclaimer and barge/ship unloader conveyors present unique fire protection concerns. Protection of the equipment and safety of the personnel is made more difficult due to the movement-in-place capabilities of the equipment and its mobility and movement along a fixed rail system. Provision of hydrants in the area may not be sufficient protection primarily due to the extreme delay in response in the event of fire emergency and the difficulty in reaching all areas involved in a fire with hand-held hose equipment.

5-4.6.4 Consideration should be given to the installation of an automatic water spray or sprinkler system over the conveyor belt and striker plate areas within the stacker-reclaimer. The water supply could be from a 3000 gal to 5000 gal (11,355 L to 18,925 L) capacity pressure tank located on-board. A fire department pumper connection should be provided so connection can be made to the fire hydrants in the area during down or repair periods to provide a more adequate water supply. Consideration should be given to protecting enclosed electrical control cabinets by a preengineered fixed automatic gaseous-type suppression system activated by a fixed temperature detection system.

5-4.6.5 Bag-type coal dust collectors that are located inside buildings or structures should be protected with automatic sprinkler or water spray systems inside of the collectors.

5-4.6.5.1 Sprinklers for bag-type dust collectors should be designed for ordinary hazard systems. Sprinkler and water spray systems should be designed for a density of 0.20 gpm (0.013 L/sec) over the projected plan area of the dust collector.

5-4.6.5.2 Protection inside dust collectors should include the clean air plenum and the bag section. If the hopper is shielded from water discharge, sprinklers also should be provided in the hopper section.

5-4.6.5.3 Consideration should be given to providing automatic sprinkler systems for bag-type dust collectors located outdoors that:

(a) are in continuous operation;

(b) process large amounts of coal dust;

(c) have limited access for manual fire fighting. An example of limited access would be collectors that have catwalks for access.

5-5 Steam Generator.

For boiler-furnaces, see NFPA 8501, *Standard for Single Burner Boiler Operation*, and NFPA 8502, *Standard for the Prevention of Furnace Explosions/Implosions in Multiple Burner Boilers*.

5-5.1 Fire Protection.

5-5.1.1 Boiler-furnaces with multiple oil-fired burners or using oil for ignition should be protected with automatic sprinkler, water spray, foam, or foam-water sprinkler systems covering the burner front oil hazard.

5-5.1.2 Boiler front fire protection systems should be designed to cover the fuel oil burners and ignitors, adjacent fuel oil piping and cable, a 20 ft (6.1 m) distance from the burner and ignitor including structural members and walkways at these levels. Additional coverage should include areas where oil may collect. Sprinkler and water spray systems should be designed for a density of 0.25 gpm/ft^2 (0.17 L/sec-m^2) over the protected area.

5-5.2 Pulverizers.

5-5.2.1 For pulverized fuel systems, see NFPA 8503, *Standard for Pulverized Fuel Systems*.

5-5.2.2 Carbon monoxide gas detection systems should be considered for pulverizers as an early warning for conditions leading to fires and explosions.

5-5.3 Boiler Feed Pumps.

5-5.3.1 Coverage of steam-driven boiler feed pumps should include oil lubrication lines, bearings, and oil reservoirs. Accidental water discharge on bearing points and hot turbine parts should be considered. If necessary, these areas may be permitted to be protected by shields and casing insulation with metal covers. Boiler feed pumps that are electric motor-driven, with lubricating or hydraulic oil hazards, may require protection depending on the quantity of oil, oil pressure, or exposure to other equipment.

5-5.3.2 Hydraulic and lubricating oil hazards associated with boiler feed pumps that are driven with steam turbines should be protected in accordance with 5-7.4.1. The use of a listed fire-resistant lubricant and hydraulic fluid can eliminate the need for fire protection systems.

5-5.3.3 Curbing or drainage or both should be provided for the steam-driven boiler feed pump oil reservoirs in accordance with Section 3-5.

5-6 Flue Gas.

5-6.1 Forced Draft, Induced Draft, and Flue Gas Recirculation Fans.

5-6.1.1 Coverage of steam-driven fans should include oil lubrication lines, bearings, and oil reservoirs. Accidental water discharge on bearings points and hot turbine parts should be considered. If necessary, these areas may be permitted to be protected by shields and casing insulation with metal covers. Water spray systems for steam turbine-driven forced draft and induced draft fans should be designed for a density of 0.25 gpm/ft^2 (0.17 L/sec-m^2) over the oil containment equipment surface. Water spray systems should be designed for 0.25 gpm/ft^2 (0.17 L/sec-m^2) for a minimum 20 ft (6.1 m) from the hazard. Combustible oil hazards associated with forced and induced draft fans driven with steam turbines should be protected with automatic sprinkler, water spray, or foam-water sprinkler systems.

5-6.1.2 Forced draft fans, induced draft fans, and flue gas recirculation fans should use a listed fire-resistant fluid for hydraulic drives. Where nonapproved hydraulic fluids are used, protection should be provided as described in 5-6.1.1.

5-6.2 Regenerative Air Heaters.

5-6.2.1 Fires have occurred in air heaters after the accumulation of appreciable quantities of unburned combustibles on plate surfaces resulting from incomplete combustion of fuel in the boiler. Incomplete combustion is most likely to occur during startup. Incomplete combustion also can occur during load changes, periods of low firing rate, or normal operation due to unstable or over-rich firing.

5-6.2.2 Fire-loss experience does not presently indicate the need for special protection for other than regenerative-type air heaters. Regenerative-type air heater fires have occurred when firing on all types of fuel. Fires have occurred most frequently when firing oil or shortly after changing to pulverized coal from oil.

5-6.2.3 Temperature sensors should be provided in the inlet and outlet ducts for both flue gas and air. An alarm should be provided in the control room to alarm when air or flue gas temperatures exceed 50°F (28°C) above normal operating temperature. Temperature sensors alone may not be adequate to provide early warning of a fire in an air heater. In large air heaters, air flow rates are high enough so that a fire will be well developed before the temperature increases enough to alarm and warn the operator. The length of time the operator has to take action is greatly reduced, and severe damage can occur. The installation of a special detection system may allow operators time to quickly detect a fire, isolate the air heater, open drains, and activate the water spray system.

NOTE: Special detection systems currently used are:

(a) Infrared detection systems to monitor rotor or stator surfaces, and

(b) Line-type detectors between intermediate and cold-end basket layers.

There has been limited fire experience with both systems to date. Low light television cameras mounted outside the air heater have a possible application in air heater fire detection.

5-6.2.4 A minimum of one observation port should be provided in the inlet and/or outlet ducts for both flue gas and air. Large air heaters may require more than one observation port. Observation ports should be placed such that they are accessible for viewing the rotor or stator surface.

5-6.2.5 A manual water spray system should be provided to protect the rotor or stator. The water spray system should be capable of being activated from the control room or from the air heater area or both. When the rotor or stator is horizontal, water spray applied to the upper surface can be expected to flow by gravity down over plate surfaces. A minimum of 0.60 gpm/ft^2 (0.41 L/sec-m^2) density is recommended. Where the rotor or stator is vertical, water spray should be applied to both sides to obtain adequate penetration. A minimum of 0.30 gpm/ft^2 (0.20 L/sec-m^2) density is recommended on both sides. Water wash systems may not be adequate to give full coverage because of rotor drive failure.

5-6.2.6 Access hatches for the use of hose streams should be provided. Hatches should be designed for quick access. A minimum of one hatch should be provided per 10 ft (3.0 m) of rotor or stator diameter. For horizontal shaft air heaters, access should be provided on both sides of the rotor or stator. For vertical shaft units, access hatches should be provided above the rotor or stator with one hatch below for units under 20 ft (6.1 m) diameter and two hatches below for units 20 ft (6.1 m) or more in diameter.

5-6.2.7 Drainage should be provided to remove suppression water to a safe area. Drains from air heaters, ducts, or both should be accessible or controlled by remotely operated valves.

5-6.2.8 A zero speed switch with alarm in the control room should be provided on the rotor shaft or on the output shaft from the fluid coupling or gear reducer. A zero speed alarm warns of stoppage of the rotor or air hoods. This could be due to failure of the drive motor or coupling that will lead to overheating of a section of the rotor or stator, which may result in a fire. Stoppage also may be caused by high temperatures generated by a fire that has caused the rotor to bind against the housing or the air hoods to bind against the stator.

5-6.3 Flue Gas Bag-Type Dust Collectors.

5-6.3.1 Flue gas bag-type dust collectors (also known as fabric filters) can be damaged by overheating or fire. Filter media can be damaged by flue gases entering at a temperature above the operating temperature of the filter media. Fires have been caused by incomplete combustion in the boiler resulting in carryover of burning particulate igniting the filter media and by maintenance operations such as cutting and welding.

5-6.3.2 Collectors equipped with bags that have an operating temperature limit exceeding 400°F (204°C) should be subdivided into compartments by noncombustible partitions. The partitions should extend through the flue gas bag area. The filter bag area provided in each compartment should be such that the fabric filter systems will not limit boiler load with one compartment fully isolated to repair damaged filter bags. The pressure drop across the fabric filter system should not increase significantly when one compartment is isolated.

5-6.3.3 Collectors equipped with other types of bags should be subdivided into compartments by partitions of 30-minute fire resistance if no automatic sprinkler protection is provided or by noncombustible partitions if sprinklers are provided. Partitions should extend from the hopper, through the bag area to the clean air plenum. Protection inside dust collectors should include the bag area. The design density should be 0.20 gpm/ft^2 (0.14 L/sec-m^2) over the plan area of the dust collector.

5-6.3.4 If automatic sprinkler protection is provided, structural design of the collector should take into consideration maximum water loading. A method should be provided for drainage of water from the hoppers.

5-6.3.5 Each compartment should be equipped with a heat detection system, arranged to alarm in a constantly attended area at a temperature 50°F (28°C) above normal operating temperature.

5-6.3.6 One of the following should be provided to prevent high temperature inlet flue gas from damaging the bags:

(a) Where permitted for emergency conditions, an automatic isolation valve and bypass duct to divert inlet gas streams around the flue gas bag collector, or

(b) A flue gas tempering water spray system in the duct between the boiler and the flue gas bag collector.

5-6.3.7 Manual fire fighting equipment should be available to personnel performing maintenance on a collector. A standpipe system should be provided such that each compartment is accessible by at least one hose system.

5-6.3.8 Access doors or hatches for manual fire fighting and viewing ports should be provided for all compartments.

5-6.4 Electrostatic Precipitators.

5-6.4.1 Electrostatic precipitators can be damaged by heat from a fire. High temperatures can warp collecting plates, decreasing collection efficiency. Combustibles may be generated by over-rich boiler-furnace firing. Solid and liquid products of incomplete combustion can be collected on plate surfaces. Ignition can occur by arcing in the electrostatic precipitator.

5-6.4.2 Temperature sensors should be provided in the inlet and outlet ducts. Alarms should be provided in the control room to indicate abnormal operating temperatures.

NOTE: Temperature sensors alone may not be adequate to provide early warning of a fire in an electrostatic precipitator.

5-6.4.3 Transformer-rectifier sets should use high fire point insulating fluids or should be of the dry type. If mineral oil insulating fluids are used, hydrants or standpipes should be located so that each transformer-rectifier set can be reached by at least one hose stream. In addition either of the following should be provided:

(a) Automatic sprinkler or automatic water spray protection. Fire protection water spray systems provided for transformer-rectifier sets should be designed for a density of 0.25 gpm/ft^2 (0.17 L/sec-m^2) over the exposed surface of the transformer-rectifier set. Automatic sprinkler systems should be designed for a density of 0.25 gpm/ft^2 (0.17 L/sec-m^2) over 3500 ft^2 (325 m^2). The drain system should be capable of handling oil spillage plus the largest design water flow from the fire protection system.

(b) Fire barrier(s) or spatial separation in accordance with Chapter 3. (*See 3-1.4 and 3-1.5.*)

5-6.5* Scrubbers and Exhaust Ducts.

5-6.5.1 General. Fires have occurred in scrubbers with combustible lining, combustible packing, or both. The fires occurred during outages and were caused by cutting and welding. Attempts to manually fight the fires were not successful since smoke and heat prevented access to the scrubber. Where scrubbers were located in buildings, there has been extensive smoke and heat damage to the building. A fire also can occur in ducts with plastic or rubber lining.

5-6.5.2 Scrubber Buildings.

5-6.5.2.1 Buildings should be constructed of materials meeting the criteria outlined in Section 3-3.

5-6.5.2.2 Where scrubbers have plastic or rubber linings, one of the following methods of protection for the building should be provided:

(a) Automatic sprinkler protection at ceiling level sized to provide 0.20 gpm/ft^2 (0.14 L/sec-m^2). The area of operation should be the area of the building or 10,000 ft^2 (930 m^2). Where draft curtains are provided the area of operation can be reduced to the largest area subdivided by draft curtains.

(b) The roof deck and supporting steel should be protected with a 1-hr fire proof coating. Building columns should be protected with a 2-hr fire proof coating from the roof to 20 ft (6 m) below the roof. Columns adjacent to scrubber openings should be protected from the roof to below the opening scrubber opening. Automatic or remotely actuated heat venting should be provided with a vent area of 1 ft^2 per 50 ft^2 of floor area.

5-6.5.2.3 If a listed less flammable fluid is not used, hydraulic and lubricating oil equipment should be protected as described in 5-7.4.

5-6.5.3 Scrubbers.

5-6.5.3.1 Materials of Construction. Scrubbers, internal piping, and ducts should be constructed of noncombustible materials, or the recommendations of 5-6.5.3.2 and 5-6.5.3.3 should be incorporated.

5-6.5.3.2 During outages, all of the following should be done:

(a) Cutting, welding, and other hot work is the most likely cause of ignition. Thus, strict controls should be enforced. Packing should be covered with fire-resistant blankets over sheet metal. Blankets should be kept wet. A charged hose and fire watch should be provided at the work area.

(b) All equipment lined with combustible material should be identified with warning signs or placards.

(c) The scrubber reservoir should be maintained full if possible or returned to service as quickly as possible during an outage.

(d) The absorber inlet and outlet damper should be closed during cutting, welding, or other hot work to reduce the induced draft. When the scrubber outlet damper is open no work should be permitted in the downstream duct or stack.

5-6.5.3.3 Fire Protection. A fire protection system should be provided during outages for absorber vessels containing combustible packing or lining and should include the following:

(a) The fire protection system can be the spray system designed for normal scrubber operation or a specially designed fire protection system. Water spray systems should be designed such that spray patterns cover the lining and packing. Where scrubber spray systems are used for fire protection, system components internal to the scrubber should be noncombustible. The water supply should be from a reliable source available during the outage.

(b) Duct systems. A fire protection system should be provided during maintenance operations. A fixed protection system on the scaffolding is recommended. The system should be designed to protect the work platform and twice the area that can be reached by workers on the platform.

(c) Due to the unique design and operating features of scrubbers, fire protection designers should consult with the scrubber manufacturer for guidance as to material selection for internal fire protection systems and specific protection design features.

(d) Standpipes should be provided such that $1^1/_2$-in. (3.8-cm) hose is available at scrubber access hatches that are open during outages.

(e) Combustible materials in the scrubber should be limited and controlled during maintenance and inspection outages.

5-6.5.4 Limestone Conveyors. Limestone conveyors for use with flue gas desulfurization systems should meet the fire protection requirements of 5-4.4.1, 5-4.4.2, 5-4.4.3, and 5-4.5.1. Conveyors critical to continued plant operation should be provided with an automatic sprinkler or water spray system over the drive pulley, and a fire detection system should be provided and interlocked to shut down the conveyor.

5-6.6 Stacks.

5-6.6.1 Noncombustible liners should be used where practical. (*See Appendix C for fire tests.*)

5-6.6.2 Combustibles should not be stored in the space between the concrete shell and the combustible liner unless the liner is adequately protected by a fire barrier. The barrier could be either a 2-hr fire barrier or a 1-hr fire barrier if automatic sprinkler protection is provided over the combustible material.

5-6.6.3 A fire protection system should be provided for maintenance operations inside plastic stack liners. A fixed protection system installed on scaffolding is recommended. It should be capable of both manual and automatic operation and designed to protect the work platform and twice the area that can be reached by workers on the platform.

5-6.6.4 Ignition sources should be eliminated when working inside plastic liners.

5-7 Turbine-Generator.

5-7.1 Hydrogen System.

5-7.1.1 General.

5-7.1.1.1 For hydrogen storage systems, see NFPA 50A, *Standard for Gaseous Hydrogen Systems at Consumer Sites*, or NFPA 50B, *Standard for Liquefied Hydrogen Systems at Consumer Sites*.

5-7.1.1.2 Bulk hydrogen systems supplying one or more generators should have automatic valves located at the supply and operable either by “dead man” type controls at the generator fill point(s) or operable from the control room. This would minimize the potential for a major discharge of hydrogen in the event of a leak from piping inside the plant. Alternatively, vented guard piping may be used in the building to protect runs of hydrogen piping.

5-7.1.1.3 Routing of hydrogen piping should avoid hazardous areas and areas containing critical equipment.

5-7.1.2 Hydrogen Seal Oil Pumps.

5-7.1.2.1 Redundant hydrogen seal oil pumps with separate power supplies should be provided for adequate reliability of seal oil supply.

5-7.1.2.2 Where feasible, electrical circuits to redundant pumps should be run in buried conduit or provided with fire retardant coating if exposed in the area of the turbine generator to minimize possibility of loss of both pumps as a result of a turbine generator fire.

5-7.1.3 Curbing or drainage or both should be provided for the hydrogen seal oil unit in accordance with Section 3-5.

5-7.1.4 A flanged spool piece or equivalent arrangement should be provided to facilitate the separation of hydrogen supply where the generator is opened for maintenance.

5-7.1.5 For electrical equipment in the vicinity of the hydrogen handling equipment, including detraining equipment, seal oil pumps, valves, etc., see Article 500 of NFPA 70, *National Electrical Code*, and Section 127 of ANSI C2, *National Electrical Safety Code*.

5-7.1.6 Control room alarms should be provided to indicate abnormal gas pressure, temperature, and percentage of hydrogen in the generator.

5-7.1.7 Hydrogen lines should not be piped into the control room.

5-7.1.8 The generator hydrogen dump valve and hydrogen detraining equipment should be arranged to vent directly to a safe outside location. The dump valve should be remotely operable from the control room or an area accessible during a machine fire.

5-7.2 Hydraulic Control System.

5-7.2.1 The hydraulic control system should use a listed fire-resistant fluid.

5-7.2.2 If a listed fire-resistant fluid is not used, hydraulic control equipment should be protected as described in 5-7.4.

5-7.2.3 Fire extinguishing systems, where required for hydraulic control equipment, should include reservoirs and stop, intercept, and reheat valves.

5-7.3 Lubricating Oil Systems.

5-7.3.1 Lubricating oil storage, pumping facilities, and associated piping should comply with NFPA 30, *Flammable and Combustible Liquids Code*.

5-7.3.2 Turbine lubricating oil reservoirs should be provided with a vapor extractor, vented to a safe outside location.

5-7.3.3 Curbing or drainage or both should be provided for the turbine lubricating oil reservoir in accordance with Section 3-5.

5-7.3.4 All oil piping serving the turbine-generator should be designed and installed to minimize the possibility of an oil fire in the event of severe turbine vibration. (*See NFPA 30, Flammable and Combustible Liquids Code; Chapter 3, Piping Systems.*)

5-7.3.5 Piping design and installation should consider the following protective measures:

(a) Welded construction.

(b) Guard pipe construction with the pressure feed line located inside the return line or in a separate shield pipe drained to the oil reservoir.

(c) Route oil piping clear of or below steam piping or metal parts.

(d) Insulation with impervious lagging for steam piping or hot metal parts under or near oil piping or turbine bearing points.

NOTE: On some turbine-generators employing the guard pipe principle, the guard piping arrangement terminates under the machine housing where feed and return piping run to pairs of bearings. Such locations are vulnerable to breakage with attendant release of oil in the event of excessive machine vibration and should be protected.

5-7.3.6 It is desirable to provide for remote operation, preferably from the control room, of the condenser vacuum break valve and the lubricating oil pumps. Breaking the condenser vacuum markedly reduces the rundown time for the machine and thus limits oil discharge in the event of a leak. See the discussion in 2-7.2 on fire emergency planning involving turbine lubricating oil fires.

5-7.3.7 Cable for operation of lube oil pumps should be protected from fire exposure. Protection may consist of separation of cable for ac and dc oil pumps or 1-hr fire resistive coating (derating of cable should be considered).

5-7.4 Fire Protection.

5-7.4.1 Turbine-Generator Area.

5-7.4.1.1 All areas beneath the turbine-generator operating floor that are subject to oil flow, oil spray, or oil accumulation should be protected by an automatic sprinkler or foam-water sprinkler system. This coverage normally includes all areas beneath the operating floor in the turbine building. The sprinkler system beneath the turbine-generator should take into consideration obstructions from structural members and piping and should be designed to a density of 0.30 gpm/ft^2 (0.20 L/sec-m^2) over a minimum application of 5000 ft^2 (464 m^2).

NOTE: To avoid water application to hot parts or other water sensitive areas and to provide adequate coverage, designs that incorporate items such as fusible element operated directional spray nozzles may be necessary.

5-7.4.1.2 Lubricating oil lines above the turbine operating floor should be protected with an automatic sprinkler system covering those areas subject to oil accumulation including the area within the turbine lagging (skirt). The automatic sprinkler system should be designed to a density of 0.30 gpm/ft^2 (0.20 L/sec-m^2).

5-7.4.1.3 Lubricating oil reservoirs and handling equipment should be protected in accordance with 5-7.4.1.1. If the lubricating oil equipment is in a separate room enclosure, protection may be provided by a total flooding gaseous extinguishing system.

NOTE 1: If the lubricating oil reservoir is elevated, sprinkler protection should be extended to protect the area beneath the reservoir.

NOTE 2: If the lubricating oil reservoirs and handling equipment are located on the turbine operating floor and not enclosed in a separate fire area, then all areas subject to oil flow or oil accumulation should be protected by an automatic sprinkler or deluge system.

5-7.4.1.4 Above the operating floor, ceiling level sprinkler systems may not be effective to protect floor level equipment and components from oil fires because of the high ceilings [typically in excess of 40 ft (12 m)]. More effective protection can be provided by containing oil spills and providing local automatic protection systems for the containment areas.

5-7.4.1.5 Foam-water sprinkler systems installed in place of automatic sprinklers described above should be designed in accordance with NFPA 16, *Standard for the Installation of Deluge Foam-Water Sprinkler and Foam-Water Spray Systems* or NFPA 16A, *Standard for the Installation of Closed-Head Foam-Water Sprinkler Systems*, and the design densities specified above.

5-7.4.1.6 Electrical equipment in the area covered by a water or foam-water system should be of the enclosed type or otherwise protected to minimize water damage in the event of system operation.

5-7.4.2 Turbine-Generator Bearings.

NOTE: Additional information concerning turbine-generator fire protection can be found in EPRI Research Project 1843-2 report, *Turbine Generator Fire Protection by Sprinkler System*, July 1985.

5-7.4.2.1 Turbine-generator bearings should be protected with a manually or automatically operated closed-head sprinkler system utilizing directional nozzles. Fire protection systems for turbine-generator bearings should be designed for a density of 0.25 gpm/ft^2 (0.17 L/sec-m^2) over the protected area.

5-7.4.2.2 Accidental water discharge on bearing points and hot turbine parts should be considered. If necessary, these areas may be permitted to be protected by shields and encasing insulation with metal covers.

5-7.4.2.3 If a manually operated water system is installed, consideration should be given to a supplemental automatic gaseous fire extinguishing system.

5-7.4.3 Exciter. The area inside a directly connected exciter housing should be protected with a total flooding automatic carbon dioxide system.

5-7.4.4 Hydrogen Seal Oil. Hydrogen seal oil units should be protected in accordance with 5-7.4.1.

5-7.4.5 Oil Storage Areas. Clean or dirty oil storage areas should be protected based on the Fire Risk Evaluation. This area generally represents the largest concentrated oil storage in the plant. The designer should consider, as a minimum, the installation of fixed automatic fire protection systems and the ventilation and drainage requirements in Chapter 3.

5-8 Electrical Equipment.

5-8.1 Control, Computer, and Communication Rooms.

5-8.1.1 Control, computer, or telecommunication rooms should meet the applicable requirements of NFPA 75, *Standard for the Protection of Electronic Computer/Data Processing Equipment*.

5-8.1.2 A smoke detection system should be installed throughout these rooms, including walk-in-type consoles, above suspended ceilings where combustibles are installed, and below raised floors. Where the only combustibles above the false ceiling are cables in conduit and the space is not used as a return air plenum, smoke detectors may be permitted to be omitted from this area.

5-8.1.3 A preaction sprinkler system for the computer or telecommunications rooms should be considered during the Fire Risk Evaluation. In addition, total flooding gaseous fire extinguishing systems should be considered for areas beneath raised floors that contain cables or for areas or enclosures containing equipment that is of high value or is critical to power generation. Individual equipment and cabinet protection could be considered in lieu of total flooding systems.

5-8.1.4 Cable raceways not terminating in the control room should not be routed through the control room.

5-8.2 Cable Spreading Room and Cable Tunnels.

5-8.2.1 Cable spreading rooms and cable tunnels should be protected with automatic sprinkler, water spray, or automatic gaseous extinguishing systems. Automatic sprinkler systems should be designed for a density of 0.30 gpm/ft^2 (0.20 L/sec-m^2) over 2500 ft^2 (232 m^2) or the most remote 100 linear ft (30 m) of cable tunnels up to 2500 ft^2 (232 m^2).

5-8.2.2 Cable spreading rooms and cable tunnels should be provided with an early warning fire detection system.

5-8.3 Grouped Electrical Cables.

5-8.3.1 Consideration should be given to the use of fire retardant cable insulation such as those passing the Flame Propagation Test of the Institute of Electrical and Electronics Engineers (IEEE-383). Grouped electrical cables should be routed away from exposure hazards or protected as required by the Fire Risk Evaluation. In particular, care should be taken to avoid routing cable trays near sources of ignition or flammable and combustible liquids. Where such routing is unavoidable, cable trays should be designed and arranged to prevent the spread of fire.

5-8.3.2 Cable trays subject to accumulation of coal dust and the spread of an oil spill should be covered by sheet metal. Where potential oil leakage is a problem, solid-bottom trays should be avoided. Changes in elevation can prevent oil travel along cables in a tray.

5-8.3.3 The Fire Risk Evaluation should consider the provision of fire suppression systems or fire retardant cable coatings or both for protection of cable concentrations from exposure fires. Care should be exercised in the selection of fire retardant coatings to ensure that derating of the cable is considered. Consideration also should be given to the ability to add or remove cables and to make repairs to cables protected with fire retardant coatings.

5-8.4 Switchgear and Relay Rooms.

Switchgear rooms and relay rooms should be provided with smoke detection systems.

5-8.5 Battery Rooms.

Battery rooms should be provided with ventilation to limit the concentration of hydrogen to 1 percent by volume. For further information refer to ANSI/IEEE 484, *Recommended Practice for*

Installation Design and Installation of Large Lead Storage Batteries for Generating Stations and Substations.

5-8.6 Transformers.

Oil-filled main, station service, and start-up transformers should be protected with automatic water spray or foam-water spray systems.

5-8.7* Substations and Switchyards.

Substations and switchyards located at the generating facility, utilizing combustible oil filled equipment should be protected by the yard fire hydrant system where practical. Spatial separation of transformers and other equipment containing over 500 gal (1893 L) of oil should be in accordance with 3-1.4. Consideration should be given to water spray protection of transformers critical to the transmission of the generated power.

5-9 Auxiliary Equipment and Other Structures.

5-9.1 Emergency Generators.

5-9.1.1 The installation and operation of emergency generators should be in accordance with NFPA 37, *Standard for the Installation and Use of Stationary Combustion Engines and Gas Turbines*.

5-9.1.2 Fire Protection.

5-9.1.2.1 Emergency generators located within main plant structures should be protected by automatic sprinkler, water spray, foam-water sprinkler, or gaseous-type extinguishing systems. Sprinkler and water spray protection systems should be designed for a 0.25 gpm/ft^2 (0.17 L/sec-m^2) density over the fire area.

5-9.1.2.2 Where gaseous suppression systems are used on combustion engines that may be required to operate during the system discharges, consideration should be given to the supply of engine combustion air and outside air for equipment cooling.

5-9.2 Storage Rooms, Offices, and Shops.

Automatic sprinklers should be provided for storage rooms, offices, and shops containing combustible materials that present an exposure to surrounding areas that are critical to plant operations. (*For oil storage rooms, see 5-7.4.5.*)

5-9.3 Warehouses.

Automatic sprinklers should be provided for warehouses that contain high-value equipment and combustible materials that are critical to power generation or that constitute a fire exposure to other important buildings.

5-9.4 Fire Pumps.

Rooms housing diesel-driven fire pumps should be protected by automatic sprinkler, water spray, or foam-water sprinkler systems. If sprinkler and water spray protection systems are provided for fire pump houses, they should be designed for a density of 0.25 gpm/ft^2 (0.17 L/sec-m^2) over the fire area.

5-9.5 Cooling Towers.

Cooling towers of combustible construction that are essential to continued plant operations should be protected by automatic sprinkler or water spray systems in accordance with NFPA 214, *Standard on Water-Cooling Towers*.

5-9.6 Auxiliary Boilers.

5-9.6.1 Auxiliary boiler-furnaces, their fuel burning systems, combustion products removal systems, and related control equipment should be designed, installed, and operated in accordance with Section 5-5.

5-9.6.2 Oil- or coal-fueled auxiliary boilers installed within main plant structures should be protected by automatic sprinkler, water spray, or foam-water sprinkler systems. A sprinkler system is preferred throughout the auxiliary boiler room on a 0.25 gpm/ft^2 (0.17 L/sec-m^2) density. As a minimum, sprinkler or water spray protection should be provided as outlined in 5-5.1.

5-9.7

Vehicle repair facilities should meet the requirements of NFPA 88B, *Standard for Repair Garages*.

Chapter 6 Identification and Protection of Hazards for Combustion Turbines

6-1 General.

6-1.1

This chapter identifies fire and explosion hazards of combustion turbine electric generating units and specifies recommended protection criteria.

6-1.2

It should be recognized that some combustion turbine generating facilities consist of manufactured modules wherein construction consists of siting these modules, providing fuel supply, essential services, and interconnections to the electric system, while other facilities consist of buildings specifically designed and built or modified for the combustion turbine generator and its auxiliaries. Therefore, some recommendations may be more suitable for one type of plant than the other.

6-2 Application of Chapters 2

through 5 and Chapter 9. The recommendations contained in Chapters 2 through 5 and Chapter 9 may apply to combustion turbine electric generating units. It is incumbent on the Fire Risk Evaluation to determine which recommendations apply to any specific combustion turbine unit. This is done by evaluating the specific hazards that exist in the facility and evaluating the level of acceptable risk for the facility. For large combustion turbine units or combined cycle plants, it is expected that most of the recommendations will apply, whereas for individual packaged combustion turbine units, many of the recommendations will not apply since the hazards described may not exist (e.g., small units may have no cable spreading room or warehouse).

6-3 General Design and Equipment Arrangement.

6-3.1

Adequate separation should be provided, as determined by the Fire Risk Evaluation, between:

(a) adjacent combustion turbine units;

(b) adjacent structures or exposures;

(c) adjacent properties (e.g., tank farms or natural gas facilities that could present a severe exposure).

6-3.2

Consideration should be given to equipment layout that is adjacent to combustion turbines and in line with planes of turbine and compressor disks that have a higher potential for damage from flying debris.

6-4 Unattended Facilities.

Facilities that are operated unattended present special fire protection concerns.

6-4.1

Consideration should be given both to the delayed response time of the fire brigade or public fire-fighting personnel (which may be several hours) and to the lack of personnel available to alert others to a fire condition.

6-4.2

The Fire Risk Evaluation should address delayed response and lack of communication. This may establish the need to provide additional fire protection measures to prevent a major fire spread prior to the arrival of fire-fighting personnel. The delayed response by personnel to the site may necessitate automatic shutoff of fire pumps.

6-4.3

If automatic water or foam fire suppression systems are utilized, a cycling deluge valve should be considered. The arrangement will depend on the type of system and the hazard protected. Thermal detection is recommended.

6-4.4

Remote annunciation of the fire-signaling panel to one or more constantly attended locations is critical for emergency response. The fire-signaling panel should be located at the entry to the unattended plant.

6-4.5

It is important that the responding fire brigade or public fire-fighting forces be familiar with access, plant fire protection systems, emergency lighting, specific hazards, and methods of fire control. This should be reflected in the plant fire emergency plan. (*See Section 2-7*.)

6-4.6

If an automatic foam system is provided for the fuel storage tanks, a cycling system could be provided to shut down the system when the foam concentrate supply is exhausted.

6-5 Combustion Turbine and Internal Combustion Engine Generators.

6-5.1 General.

6-5.1.1 NFPA 37, *Standard for Installation and Use of Stationary Combustion Engines and Gas Turbines*, addresses engines and turbines not exceeding 7500 HP. It includes important items of design, siting, protective devices, and fueling that apply regardless of engine size.

6-5.1.2 Site specific design considerations or manufacturers typical design will govern what equipment has enclosures or how many separate enclosures will be provided for the combustion turbines or the diesel engines. The combustion turbine generator is frequently supplied as a complete power plant package with equipment mounted on skids or pads and provided with metal enclosures forming an all-weather housing. In addition to being weather-tight, the enclosures are designed to provide thermal and acoustical insulation. Smaller diesel engine plants might involve enclosures for equipment but more commonly engine generators are installed in a row in an open room or hall.

6-5.1.3 The major hazards associated with combustion turbine or diesel electric generator units are:

(a) Flammable and combustible fuels; and

(b) Hydraulic and lubricating oils.

6-5.1.4 In the event of a pipe failure, large amounts of oil or fuel could be released and ignite on contact with hot metal parts. In addition to external fire hazards, combustion turbines are subject to the hazard of uncontrolled internal fires if flameout occurs and the fuel is not shut off immediately, or if fuel is admitted to a hot engine and ignition does not occur. Crankcase explosions in diesel engines have caused large external fires. Other hazards associated with the combustion turbine or internal combustion engine generator are:

(a) Electrical equipment; and

(b) Large amounts of filter media and enclosure insulation.

NOTE: Diesel electric plants do not normally use large amounts of filter media and enclosure insulation.

6-5.1.5 In the event of a problem with a diesel engine, shutdown may be difficult. Several different methods, operating independently, should be provided. These can include centrifugally tripped (over speed condition) spring operated fuel rack closure, governor fuel rack closure, electro-pneumatic fuel rack closure, or air inlet guillotine type air shutoff.

6-5.2 Prevention of Internal Fires in Combustion Turbines.

6-5.2.1 Combustion turbines should have flame detectors in the combustion section to detect flameout or ignition failure during startup. In the case of flameout the fuel should be rapidly shut off. If ignition is not achieved within a normal startup time, then the control system should abort the startup and close the fuel valves.

NOTE: When a flameout occurs, fuel valves should close as rapidly as possible (preferably less than 1 second) to preclude the accumulation of unburned fuel in the combustion chamber. Loss experience documents that fires or explosions have occurred in systems where the fuel isolation was not achieved within 3 seconds.

6-5.2.2 In order to prevent conditions that could cause a fire while the unit is operating, control packages for combustion turbines should include the following monitors:

(a) Turbine speed sensor, independent of the main governor, for tripping on overspeed;

(b) Vibration monitors at the main turbine bearings, for tripping on excessive vibration; and

(c) Turbine exhaust temperature monitor, for tripping on high temperature.

NOTE: Monitors for conditions (b) and (c) should have a lower alarm point to alert operators of deteriorating operating conditions. See ANSI B133.4, *Gas Turbine Control and Protection Systems*.

6-5.2.3 Two safety shutoff valves in series on the main fuel line should be used to minimize the likelihood of fuel leaking into the engine. On gas systems an automatic vent to the outside atmosphere should be provided between the two valves.

6-5.3 Prevention of External Fires in Combustion Turbines and Diesel Engines.

6-5.3.1 Piping systems supplying flammable and combustible liquids and gases should be designed to minimize oil and fuel piping failures as described below.

(a) If rigid metal piping is used, it should be designed with freedom to deflect with the engine, in any direction, at the interface with the turbine. This recommendation also should apply to hydraulic lines that are connected to accessory gearboxes or actuators mounted directly in the engine. Properly designed metallic hose is an alternative for fuel, hydraulic, and lube oil lines in high vibration areas, between rigid pipe supply lines and manifolds, and the points of entry at the engine interface.

(b) Rigid piping connected directly to the turbine should be supported such that failures will not occur due to the natural frequency of the piping coinciding with the rotational speed of the combustion turbine. Care should be taken in the design of pipe supports to avoid vibrations induced by other equipment that may excite its natural frequency.

(c) Welded pipe joints should be used where practical. Threaded couplings and flange bolts in fuel and oil piping should be assembled using a torque wrench and torqued to the manufacturer's requirements. Couplings should have a positive locking device to prevent unscrewing.

(d) Instrumentation tubing, piping, and gauges should be protected from accidental mechanical damage. Sight glasses should be unbreakable.

(e) Where practical, lubricating oil lines should use pipe guard construction with the pressure feed line located inside the return line.

6-5.3.2 For diesel engines, the following monitors should be provided:

(a) Speed sensors, independent of governors; and

(b) High exhaust gas temperature alarm with shutdown.

6-5.3.3 In many units the lubricating oil is used for both lubrication and hydraulic control. For combined systems, a listed fire-resistive fluid should be considered. If separate systems are used, the hydraulic control system should use a listed fire-resistive hydraulic fluid, and a listed fire-resistant fluid should be considered for the lubricating system.

NOTE: Diesel engines do not normally have any hydraulic systems.

6-5.3.4 Combustible gas detector(s) should be considered for the enclosure where the fuel for the gas turbine or diesel engine is natural gas or other gaseous-type fuels.

6-5.3.5 For recommendations regarding containment and drainage of liquids, see Section 3-5.

6-5.4 Fire Protection for Combustion Turbines and Diesel Electrical Generators.

6-5.4.1 General.

6-5.4.1.1 Determination of the need for fire suppression for the combustion turbine engine should be based on consideration of the value of the unit, consequences of loss of the unit, and vulnerability of adjacent structures and equipment to damage.

6-5.4.1.2 Water suppression systems, where provided, should follow the recommendations in Chapter 5 and the following criteria:

(a) Water spray nozzles provided to protect the combustion turbine power bearing housings behind the exhaust duct should be directed based on unit geometry to avoid possible water damage.

(b) Automatic sprinkler or water spray protection should be provided for exposed oil piping and areas on the floor under the turbine where leaking oil may collect.

(c) Accidental water discharge on bearing points and hot turbine parts should be considered. If necessary, these areas can be protected by shields and encasing insulation with metal covers.

(d) Fuel valves should be arranged to close automatically on water flow.

(e) Turbine chargers on diesel engines constitute a part of the hazard and protection should be provided.

6-5.4.1.3 Lubricating oil reservoirs and handling equipment should be protected in accordance with 5-7.3.2 and 5-7.4.1.3.

6-5.4.2 Total Flooding Gaseous Systems.

6-5.4.2.1 Where total flooding gaseous systems are used, the turbine enclosure should be arranged for minimum leakage by automatic closing of the doors, ventilation dampers, and automatic shutdown of the fans and other openings. Combustion turbine or diesel engine compartments are designed to be capable of nominally air-tight closure. During operation there is, however, a need for substantial amounts of secondary cooling (compartment ventilation) air. This air can be moved through the compartments by fans or venturi action from the turbine combustion or diesel engine air. This air flow will not stop immediately upon shutdown, and, therefore, it should be considered in the extinguishing system design.

6-5.4.2.2 Gas design concentrations should be held as long as the hazards of hot metal surfaces above the auto-ignition temperature and uncontrolled combustible liquid flow exist (consult manufacturer for cool down times). Proper gaseous extinguishing system design dictates that the design concentration be held in the compartment for the cooling time discussed above to take place. This has been shown to be around 20 minutes for many areas, but can be substantially longer. It also has been shown that the initial gas discharge will not hold for a 20-minute time period in most turbine or engine compartments. Therefore, the designer should determine the level of an extended added discharge that is necessary to maintain fire extinguishment. This usually requires discharge testing to determine if design concentrations can be maintained. Where gas concentrations cannot be effectively maintained, an alternative system, such as high-expansion foam or water extinguishing system, may be desirable.

6-5.4.2.3 System operations should be arranged to close the fuel valves.

6-5.4.2.4 Maintenance of total flooding systems is particularly critical. In addition to the extinguishing equipment, the integrity of the enclosure to be flooded and the interlocks between the two should be maintained.

6-5.4.2.5 It should be noted that deep seated fires, such as oil-soaked insulation, may be present and will require manual extinguishment after the gaseous system soak time.

6-5.4.2.6 For combustion turbines or diesel engines located indoors, provisions should be addressed for safely removing the gas and potential toxic combustion by-products from the turbine enclosure following system actuation.

6-5.4.3 Localized Extinguishing Systems.

6-5.4.3.1 Where units are not enclosed and a first level of protection is desired that will operate before sprinklers, or where sprinklers are not installed, a localized extinguishing system might be appropriate. Such a system should be of an approved local application type such as water mist, carbon dioxide, dry chemical, or other approved gaseous extinguishing system.

6-5.4.3.2 Discharge rates and duration of discharge should be such that cooling and shutdown occurs to prevent reignition of the fire. System operation should be arranged to close fuel valves.

6-5.4.3.3 The positioning of local application nozzles should be such that maintenance access to the turbine or engine is maintained.

6-5.4.4 High-Expansion Foam Systems. Where total flooding high-expansion foam systems are used for the enclosure where the turbine is located, system operation should be arranged to close the fuel valves.

6-5.5 Inlet Air Filter.

6-5.5.1 Air filters should be of a type that will not burn freely when exposed to fire. Filters qualifying as Class 1, as tested in accordance with UL 900, *Standard for Safety Test Performance of Air Filters*, meet these requirements.

6-5.5.2 Manual fire-fighting equipment should be available to personnel performing maintenance on air filters.

6-5.5.3 Access doors or hatches should be provided for manual fire fighting on large air filter structures.

6-5.6 Generators.

6-5.6.1 Hydrogen systems should comply with recommendations in 5-7.1 and 5-7.4.6.

6-5.6.2 Fire protection should be provided in accordance with 6-5.4.1, 6-5.4.2, 6-5.4.3, or 6-5.4.4.

6-5.6.3 Air-cooled generators should be tightly sealed against the ingress of moisture in the event of discharge (accidental or otherwise) of a water spray system. Sealing should be positive, such as by a gasket or grouting, all around the generator housing.

NOTE: The type of generator used with diesel engines is normally provided with an open drip proof enclosure. Shielding might be appropriate with water system, i.e., sprinklers or deluge.

6-5.7 Starting Equipment.

Fire protection should be provided for the starting equipment on the combustion turbine and its enclosure, based on consideration of the factors in 6-5.4.1.

NOTE: Large diesels are started with compressed air from an air receiver and do not require starting the engine.

6-6 Electrical Equipment.

6-6.1 Control Enclosures.

The size of the combustion turbine generator and the site design determine whether control enclosures are provided. Control enclosures normally are used in remote locations and are designed to be unattended. Control enclosures contain turbine and generator control panels, switchgear, batteries, relays, and indication gauges.

6-6.2 Auxiliary Electrical Equipment Enclosures.

Auxiliary electrical equipment enclosures, where provided, normally contain static excitation equipment, switchgear, current transformers, potential transformers, grounding transformers, and other electrical equipment.

6-6.3

A smoke detection system should be provided for alarm only and early warning of an electrical fire.

6-6.4

A total flooding gaseous suppression system should be considered for the enclosures.

6-7 Combined Cycle Units.

6-7.1 Heat Recovery Steam Generators.

Heat recovery steam generators using supplemental firing should be designed and protected in accordance with Section 5-5.

6-7.2 Steam Turbines.

Steam turbines, generators, and their associated hazards should be designed and protected in accordance with Section 5-7.

Chapter 7 Alternative Fuels

7-1 General.

This chapter identifies fire and explosion hazards of alternative fuel (e.g., RDF, MSW, biomass) fired electric generating plants and specifies recommended protection criteria.

7-2 Application of Chapters 2 through 5 and Chapter 9.

The recommendations contained in Chapters 2 through 5 and Chapter 9 may apply to alternative fuel fired electric generating station units. It is incumbent upon the Fire Risk Evaluation to determine which recommendations apply to any specific alternative fuel fired unit. This is done by evaluating the specific hazards that exist in the facility and determining the level of acceptable risk for the facility. It is expected that most of the recommendations will apply to all units, except where:

(a) Size and specific design eliminate certain hazards (e.g., H_2 seal oil units, cable spreading rooms, or warehouses), and

(b) The Fire Risk Evaluation indicates a single source of water (e.g., a single tank) is considered adequate and reliable.

7-3 Mass Burn Fuels.

7-3.1 General.

7-3.1.1 This section (Section 7-3) identifies fire and explosion hazards that are unique to the use of municipal solid waste (MSW) as a boiler fuel by means of a process that includes the hauling of MSW directly to a tipping floor or storage pit and burning without any special processing. MSW is municipal solid waste consisting of commonly occurring residential and light commercial waste.

7-3.1.2 The major fire and explosion hazards associated with mass burn units are:

(a) Sourcing, receipt, handling, and storage of large quantities of MSW.

(b) Unsuitable waste entering the facility. Examples include certain hydrocarbons, flammable liquids, metal dusts, acetylene, explosives, etc.

(c) Hydraulic and lubricating oils associated with the processing equipment.

(d) Improperly maintained electrical equipment.

(e) Large amounts of MSW accumulating in unsuitable areas as a result of spillage or handling.

(f) Inadequate dust control.

7-3.2 Plant Arrangement.

7-3.2.1 A MSW hot-load unloading area should be designated and separated from other areas (preferably outdoors) so that loads containing smoldering or other suspect constituents can be segregated. Such areas should be properly monitored and equipped to promptly extinguish incipient fires before recombining with other MSW.

7-3.2.2 The refuse pit is normally enclosed on three sides, up to the charging level, by reinforced concrete walls. The thickness of the walls vary with facility design, but should provide a minimum of 2-hr fire separation.

7-3.2.3 Exposed steel columns located at the front of the refuse pit should be protected against structural damage caused by heat (fire). This protection could include concrete encasement, water spray, or other suitable alternatives and should extend from the base of the column to the roof of the refuse pit enclosure. Care should be taken to protect fire-proofing from mechanical damage.

7-3.2.4 Smoke or heat vents should be considered in accordance with 3-4.1.

7-3.2.5 Overhead cranes are often used to mix and stock the refuse within the pit. Undesirable waste (large items such as refrigerators) is often separated from the waste stock by the crane operator for offsite disposal or for shredding/processing (*see 7-3.5*) prior to replacement into the waste stock. All other items are loaded directly into boiler feed hoppers without processing. In addition, the acceptable method for extinguishment of small fires is also direct loading of the smoldering refuse into the hoppers by the crane operator. The following considerations should be given with respect to the crane operator's pulpit:

(a) Locating the pulpit such that operator safety is not compromised.

(b) Ability to have a clear and unobstructed view of all storage and charging areas.

(c) Providing self-contained breathing apparatus for operator egress.

(d) Providing direct communication with the boiler control room and floor manager.

(e) Ability to activate fire protection equipment.

7-3.2.6 Boiler feed equipment, such as a chute or metering bin, should be of noncombustible material and designed to minimize pockets or corners that could cause combustible material to build up. Video monitoring should be considered for locations not readily visible to plant staff. For further guidance, see NFPA 8505, *Recommended Practice for Stoker Operation*.

7-3.2.7 Mass burn facilities utilizing hammermills and flailmills should refer to the criteria in 7-4.2.3.

7-3.3 Prevention of Fires and Explosions in Mass Burn Units.

7-3.3.1 A communication system should be provided between the floor manager and the control room to expedite assistance in the event of fire.

7-3.3.2 The floor operators should ensure that MSW is continuously moved to the processing or storage areas. Vehicles loaded with MSW should not be parked in the building during idle periods.

7-3.3.3 A regular program of housekeeping should be established to keep concentrations of combustible material to a minimum.

7-3.3.4 Operational experience has demonstrated that roving operators and other plant personnel have been key factors in detection of fires and unsafe conditions. It is important that they be properly trained to observe and react to incipient fire situations. These should be reported to the control room operator for evaluation to determine what action is to be taken.

NOTE: The traffic pattern should minimize any requirement for storage of the MSW in tightly enclosed containers, such as trailers, to minimize the occurrence of spontaneous combustion of the fuel.

7-3.4 Fire Protection.

7-3.4.1 Hose stations designed in accordance with NFPA 14, *Standard for the Installation of Standpipe and Hose Systems*, should be located throughout MSW storage (tipping building), charging floor, firing floor, hydraulic area, and residue building. Due to the high frequency of use, the following points should be considered:

(a) Location and physical protection so as to avoid potential damage due to traffic patterns.

(b) Size and number to be determined for unique plant geometry (e.g., push walls).

(c) Ease of use, maintenance, and storage, such as through the use of continuous-flow, noncollapsible hose reels.

(d) Protection from freezing in unheated areas.

NOTE: Based on plant geometry, combustible loading, and staff size, a 250-gpm (946-L/min) monitor nozzle may be needed in lieu of or in conjunction with hoses.

7-3.4.2 MSW conveyors should be protected in accordance with 5-4.6.2.

NOTE: Conveyors can be considered protected by overhead building protection if not enclosed or hooded.

7-3.4.3 Hydraulic equipment, reservoirs, coolers, and associated oil-filled equipment should be provided with automatic sprinkler or water spray protection. Sprinklers or spray nozzles should be over oil-containing equipment and for 20 ft (6.1 m) beyond in all directions. A density of 0.25 gpm/ft^2 (10.19 L/min-m^2) should be provided.

Exception: Where a listed fire-resistant fluid is used, protection is not needed.

7-3.4.4 The tipping/receiving building should be provided with automatic sprinkler protection throughout. Systems should be designed for a minimum of 0.25 gpm/ft^2 (10.19 L/min-m^2) over the most remote 3000 ft^2 (279 m^2) (increase by 30 percent for dry pipe systems) of floor area with the protection area per sprinkler not to exceed 130 ft^2 (120 m^2). High temperature sprinklers [250°F to 300°F (121°C to 149°C)] should be used.

NOTE: The above requirements are based on storage heights not exceeding 20 ft (6.1 m).

7-3.4.5 The MSW Storage Pit, Charging Floor, and Grapple Laydown Areas.

7-3.4.5.1 Automatic sprinkler protection should be provided throughout the refuse enclosure to protect the entire roof area against structural damage. Systems should be designed for a minimum of 0.20 gpm/ft^2 (8.15 L/min-m^2) over the most remote 3000 ft^2 (279 m^2) (increase by 30 percent for dry pipe systems) of pit/floor area with the protection area per sprinkler not to exceed 100 ft^2 (9.3 m^2). High temperature sprinklers [250°F to 300°F (121°C to 149°C)] should be used. Exposed steel column protection, where provided, should be designed in accordance with NFPA 15, *Standard for Water Spray Fixed Systems for Fire Protection*, and can be connected to the overhead sprinkler system. Due to the distance between the bottom of the refuse pit and the sprinkler system, manual hoses and monitor nozzles should be considered as the primary means of fighting a MSW storage pit fire.

7-3.4.5.2 In addition to sprinkler protection, the storage pit should be provided with monitor nozzle protection designed to furnish a minimum of 250 gpm (946 L/min) at 100 psi (689 kPa) at the tip. Monitors should be located so as to allow for coverage of all pit areas with at least two (2) streams operating simultaneously. Due to frequency of use and potential for operator fire exposure, oscillating monitor nozzles with manual override should be provided.

7-3.4.6 Particular care should be taken in the selection of fire detection devices in consideration of harsh and dusty environments and high air flows.

7-3.5 Explosion Suppression.

Mass burn facilities utilizing hammermills and flailmills for processing of oversize bulky waste should follow the recommendations of 7-4.2.3.

NOTE: Rotary shears utilizing manual or selective feeding demonstrate less of a hazard than hammermills and flailmills due to elimination of hazardous wastes by the operator during the feeding process.

7-4 Refuse Derived Fuels (RDF).

7-4.1 General.

7-4.1.1 This section (Section 7-4) identifies fire and explosion hazards that are unique to the processing of municipal solid waste (MSW) into refuse derived fuels (RDF). RDF is a boiler fuel manufactured by means of a process that includes storing, shredding, classifying, and conveying the waste to a fuel storage area. It is then conveyed to the boiler through a metering device.

7-4.1.2 The major fire and explosion hazards associated with RDF fired units are:

(a) Sourcing, receipt, handling, and storage of large quantities of MSW.

(b) Unsuitable waste entering the processing stream. Examples include certain hydrocarbons, flammable liquids, metal dusts, acetelyne, explosives, etc. In the event of unsuitable material entering the processing stream, severe explosion and fire could result in the shredders or flailmills.

(c) Handling and storage of large quantities of RDF.

(d) Hydraulic and lubricating oils associated with the processing equipment.

(e) Improperly maintained electrical equipment.

(f) Large amounts of MSW and RDF accumulating in unsuitable areas as a result of spillage, handling, or processing.

(g) Inadequate dust control.

7-4.2 Plant Arrangement.

7-4.2.1 Fire areas should be separated from each other by approved means. In addition to the applicable requirements of 3-1.1.2 and 3-1.1.3, it is recommended that, as a minimum, fire area boundaries be provided to separate:

(a) the tipping floor (including the MSW storage);

(b) the processing area;

(c) RDF storage.

7-4.2.2 Specific MSW and RDF hot-load unloading areas should be designated and separated from other areas (preferably outdoors) so that loads containing smoldering or other suspect constituents can be segregated. Such areas should be properly monitored and equipped to promptly extinguish incipient fires before recombining with other MSW and RDF.

7-4.2.3 There is a potential fire and explosion hazard with the use of hammermills and flailmills and associated dust collection equipment. During the size-reduction process flammable or explosive materials in the waste stream may be ignited.

7-4.2.3.1 The primary shredder and associated dust collectors should be located within an enclosure of damage-limiting construction. It is preferable that the enclosure be detached from the main building. Other alternatives included are locations:

(a) outside of, but sharing a common wall with the main building;

(b) inside of the main building, along an outside wall;

(c) within the main building.

CAUTION: In view of the difficulties in preventing and controlling all types of shredder explosions, it is important to isolate the shredder and surrounding enclosure from vulnerable equipment and occupied areas in the plant. Consideration should be given to the protection of operating personnel or visitors from the potential blast zone.

7-4.2.3.2 Secondary shredders do not exhibit as significant a fire and explosion potential as primary shredders. Where specific designs do not eliminate the potential for explosions in the secondary shredder, refer to 7-4.2.3.1.

7-4.2.3.3 Shredders, shredder enclosures, and openings into the enclosure should be designed so that, by a combination of venting and wall strength, they will resist a postulated worst credible case explosion. Consideration should be given to a substantial increase in explosive pressure as a result of venting of shredders into a combustible vapor-air mixture within the enclosure. It is recommended that designers seek guidance from those having specialized experience in the analysis of such hazards, including specifying and constructing of explosion venting and shredder enclosures.

NOTE: An example of the postulated worst credible case explosion might be an acetylene tank. Explosions involving detonable material are beyond the scope of this document.

7-4.2.3.4 Platforms at intermediate elevations should be of open grating to reduce obstructions to the effective vent area.

7-4.2.3.5 Electrical equipment located inside the shredder enclosure should be rated for use in both hazardous vapor and dust atmospheres in accordance with Articles 500 and 501 of NFPA 70, *National Electrical Code*.

7-4.2.3.6 Service panels or controls for the shredder should be located so as not to expose operating personnel to the blast zone.

7-4.2.3.7 Explosion venting should be sized using the hydrogen nomographs as described in NFPA 68, *Guide for Venting of Deflagrations*. Where ducts are used to vent explosions to the outside, consideration should also be given to increased pressure caused by the length of the vent duct. If the vent area available is inadequate for sufficient explosion venting because of the height of the vent stack or other factors, an explosion suppression system in the shredder should be used to augment the venting arrangement. Refer to 7-4.5.

7-4.2.3.8 Where access door assemblies are provided for primary shredder enclosure, they should be kept secured to prevent unauthorized access when the equipment is operating. The access door assemblies should have the same pressure rating as the enclosure.

7-4.2.4 Boiler Feed Equipment.

7-4.2.4.1 Boiler feed equipment, such as a metering bin, should be of noncombustible material and designed to minimize pockets or corners that could cause combustible material to build up. Video monitoring should be considered for locations not readily visible to plant staff. For further guidance, see NFPA 8505, *Recommended Practice for Stoker Operation*.

7-4.2.4.2 Access hatches should be provided to allow operating personnel to break up accumulations of combustible material or plug gauges. In addition, the hatches should be placed so that the stream from a fire hose can be directed onto a fire that may occur inside the equipment.

NOTE: For personnel safety considerations, see NFPA 8505, *Recommended Practice for Stoker Operation*, for further guidance.

7-4.2.5 Smoke or heat vents should be considered in accordance with 3-4.1.

7-4.3 Prevention of Fires and Explosions in RDF Units.

7-4.3.1 A communication system should be provided between the floor manager and the control room to expedite assistance in the event of fire.

7-4.3.2 The floor operators should ensure that MSW is continuously moved to the processing or storage areas. Vehicles loaded with MSW or RDF should not be parked in the building during idle periods.

7-4.3.3 A regular program of housekeeping should be established to keep concentrations of combustible material to a minimum.

7-4.3.4 The process should be designed to minimize the production of dust. Dust collected in a dust collection system, baghouse, or cyclone should be discharged downstream of the collection system, back to the conveying system, or back to the residue or waste stream. For additional guidance, see 5-4.3.4.

7-4.3.5 Operational experience has demonstrated that roving operators and other plant personnel have been key factors in detection of fires and unsafe conditions. It is important that they be properly trained to observe and react to incipient fire situations. These should be reported to the control room operator for evaluation to determine what action is to be taken.

NOTE: The traffic pattern should minimize any requirement for storage of the MSW or RDF in tightly enclosed containers, such as trailers, to minimize the occurrence of spontaneous combustion of the fuel.

7-4.4 Fire Protection.

7-4.4.1 Hose stations designed in accordance with NFPA 14, *Standard for the Installation of Standpipe and Hose Systems*, should be located throughout MSW storage (tipping building), processing structures, and RDF storage structures. Due to the high frequency of use, the following points should be considered:

(a) Location and physical protection so as to avoid potential damage due to traffic patterns.

(b) Size and number to be determined for unique plant geometry (e.g., push walls).

(c) Ease of use, maintenance, and storage, such as through the use of continuous-flow, noncollapsible hose reels.

(d) Protection from freezing in unheated areas.

NOTE: Based on plant geometry, combustible loading, and staff size, a 250-gpm (946 L/min) monitor nozzle may be needed in lieu of or in conjunction with hoses.

7-4.4.2 Based on the combustible loading, location, and essential use, an automatic sprinkler system should be considered for dust collectors, baghouses, and cyclone type separators. See 5-4.6.5.

7-4.4.3 MSW and RDF conveyors should be protected in accordance with 5-4.6.2.

NOTE: Experience has shown that shredder discharge conveyors are particularly susceptible to high fire frequencies. Consideration should be given to the use of water spray systems in conjunction with spark detection in these cases. Conveyors other than shredder discharge can be considered protected by overhead building protection, if not enclosed or hooded.

7-4.4.4 Interlocks. The actuation of a fire suppression system should cause equipment it protects to shut down. With the shutdown of the equipment, the upstream feed conveyors should also shut down to stop feeding combustible material to the fire, while downstream conveyors should be stopped to prevent the spread of the fire. A manual override should be provided.

NOTE: Where a facility has a rigidly enforced operating sequence and satisfies itself and the authority having jurisdiction that the operating practices and the judgment of the plant operators provide acceptable protection, this interlock with the fire protection system may be permitted to be provided through operator action in accordance with operating procedures.

7-4.4.5 Classifiers/trommels, such as rotating screens, should be provided with water spray protection to prevent fire from propagating downstream through the screen. Systems should be designed for a minimum of 0.25 gpm/ft^2 (10.19 L/min-m^2) of the entire screen area with nozzles no more than 10 ft (3.0 m) on center. Consideration should be given to avoiding physical damage from mobile equipment operation in the area and from the material being processed.

7-4.4.6 Hydraulic equipment, reservoirs, coolers, and associated oil-filled equipment should be provided with automatic sprinkler or water spray protection. Sprinklers or spray nozzles should be over oil-containing equipment and for 20 ft (6.1 m) beyond in all directions. A density of 0.25 gpm/ft^2 (10.19 L/min-m^2) should be provided.

Exception: Where a listed fire-resistant fluid is used, protection is not needed.

7-4.4.7 The tipping/receiving building should be provided with automatic sprinkler protection throughout. Systems should be designed for a minimum of 0.25 gpm/ft^2 (10.19 L/min-m^2) over the most remote 3000 ft^2 (279 m^2) (increase by 30 percent for dry pipe systems) of floor area with the protection area per sprinkler not to exceed 130 ft^2 (12.0 m^2). High temperature sprinklers [250°F to 300°F (121°C to 149°C)] should be used.

NOTE: The above requirements are based on storage heights not exceeding 20 ft (6.1 m).

7-4.4.8 The processing building should be provided with automatic sprinkler protection throughout. Systems should be designed for a minimum of 0.25 gpm/ft^2 (10.19 L/min-m^2) over the most remote 3000 ft^2 (279 m^2) (increase by 30 percent for dry pipe systems) of floor area with the protection area per sprinkler not to exceed 130 ft^2 (12.0 m^2).

NOTE: Due to the large quantity of platforms, equipment, and walkways, care should be taken to include coverage under all obstructions greater than 4 ft (1.2 m) wide.

7-4.4.9 The RDF storage building should be provided with automatic sprinkler protection throughout. Systems should be designed for a minimum of 0.35 gpm/ft^2 (14.26 L/min-m^2) over the most remote 3000 ft^2 (279 m^2) (increase by 30 percent for dry pipe systems) of floor area with the protection area per sprinkler not to exceed 100 ft^2 (9.3 m^2). High temperature sprinklers [250°F to 300°F (121°C to 149°C)] should be used. Storage heights in excess of 20 ft (6.1 m) will require higher design densities.

7-4.4.10 The RDF boiler feed system area, including bins, hoppers, chutes, conveyors, etc., should be considered for automatic sprinkler protection. Where provided, the systems should be designed for a minimum of 0.20 gpm/ft^2 (8.15 L/min-m^2) over the most remote 2000 ft^2 (185.8 m^2) (increase by 30 percent for dry pipe systems) of floor area with the protection area per sprinkler not to exceed 130 ft^2 (12.0 m^2). Internal, as well as external, protection also should be considered depending upon specific equipment design, ceiling heights, and accessibility for manual fire fighting.

7-4.4.11 Shredder enclosures should be provided with automatic sprinkler or water spray protection. Systems should be designed for a minimum of 0.25 gpm/ft^2 (10.19 L/min-m^2) over the most remote 3000 ft^2 (279 m^2) (increase by 30 percent for dry pipe systems) of floor area with the protection area per sprinkler not to exceed 100 ft^2 (9.3 m^2). Water spray protection should also be provided within the shredder housings at intake and discharge chutes and within vent shafts.

7-4.4.12 The environment should be considered in selecting detection devices. Heat detection is most reliable under conditions encountered in process areas. Smoke detection should not be used in process areas. If flame detectors are used, an air sweep of the lens should be provided.

7-4.5 Explosion Suppression.

7-4.5.1 Explosion suppression systems should be considered for protection of shredders. If such systems are selected, they should be designed and installed by qualified individuals using listed components. See NFPA 69, *Standard on Explosion Prevention Systems*, for further guidance.

7-4.5.2 Explosion suppression system detectors and agent distribution should cover the entire shredder volume and all contiguous areas, including inlet and discharge conveyors, reject chutes, and dust collection systems.

7-4.5.3 Mountings for explosion suppression system detectors and extinguishers should be cleaned frequently to ensure successful operation. Mountings, which include provisions for air purges, pneumatic rodding, and manual cleanout, have been found to be effective.

7-5 Biomass Fuels.

7-5.1 General.

7-5.1.1 This section (Section 7-5) identifies fire and explosion hazards that are unique to the processing of forest and agricultural by-products (e.g., woodchips, rice hulls, sugar cane, etc.) into boiler fuel manufactured by means of a process that can include, but is not limited to, storing, shredding, classifying, and conveying the biomass to a fuel storage area and conveying it from the storage area to feed the boiler through a metering device. In general, biomass fuels are such that fires of low to moderate intensity would be expected. There can be cases, however, where fuel type and processing will present a greater fire hazard and so require a higher level of protection.

7-5.1.2 The major fire and explosion hazards associated with biomass fired units are:

(a) Sourcing, receipt, handling, and storage of large quantities of biomass.

(b) Unsuitable biomass (e.g., herbicides, explosives, flammable liquids, tramp metal) entering the processing stream.

(c) Hydraulic and lubricating oils associated with the processing equipment.

(d) Improperly maintained electrical equipment.

(e) Large amounts of biomass accumulating in unsuitable areas as a result of spillage, handling, or processing.

(f) Inadequate dust control.

7-5.2 Plant Arrangement.

7-5.2.1 The initial biomass receiving and storage area, whether indoors or outdoors, should be designed in accordance with:

(a) NFPA 46, *Recommended Safe Practice for Storage of Forest Products*

(b) NFPA 61, *Standard for the Prevention of Fires and Dust Explosions in Agricultural and Food Products Facilities*

(c) NFPA 80A, *Recommended Practice for Protection of Buildings from Exterior Fire Exposures*

(d) NFPA 231, *Standard for General Storage*, Appendix C

(e) NFPA 299, *Standard for Protection of Life and Property from Wildfire*

(f) NFPA 664, *Standard for the Prevention of Fires and Explosions in Wood Processing and Woodworking Facilities*.

7-5.2.2 Specific biomass unloading areas should be designated and separated from other areas (preferably outdoors) so that loads containing smoldering or other suspect constituents can be segregated. Such areas should be properly staffed and equipped to promptly extinguish incipient fires before recombining with other biomass.

7-5.2.3 Where process or handling equipment involves biomass materials with particle size less than 80 mesh and with moisture content less than 30 percent by volume, a potential explosion hazard exists. Refer to NFPA 68, *Guide for Venting of Deflagrations*; NFPA 69, *Standard on Explosion Prevention Systems*; and NFPA 664, *Standard for the Prevention of Fires and Explosions in Wood Processing and Woodworking Facilities*, for further guidance.

7-5.2.4 Fire areas should be separated from each other by approved fire barriers, spatial separation, or other approved means. In addition to the requirements of 3-1.1.3, it is recommended that, as a minimum, fire area boundaries be provided to separate:

(a) the receiving/storage area; and

(b) the processing area.

7-5.2.5 Boiler feed equipment, such as a metering bin, should be of noncombustible material and designed to minimize pockets or corners that could cause combustible material to build up. Video monitoring should be considered for locations not readily visible to plant staff. Refer to NFPA 8501, *Standard for Single Burner Boiler Operation*; NFPA 8502, *Standard for the Prevention of Furnace Explosions/Implosions in Multiple Burners*; NFPA 8503, *Standard for Pulverized Fuel Systems*; NFPA 8504, *Standard on Atmospheric Fluidized-Bed Boiler Operation*; and NFPA 8505, *Recommended Practice for Stoker Operation*.

7-5.2.6 Where access hatches are provided, they should allow operating personnel to break up accumulations of combustible material or plug gauges. In addition, the hatches should be placed so that the stream from a fire hose can be directed onto a fire that may occur inside the equipment.

NOTE: For personnel safety considerations, see NFPA 8505, *Recommended Practice for Stoker Operation*, for further guidance.

7-5.2.7 Smoke or heat vents should be considered in accordance with 3-4.1.

7-5.2.8 For biomass facilities utilizing processes described in 7-5.2.4, refer to 7-3.2.3.

7-5.3 Prevention of Fires and Explosions in Biomass Units.

7-5.3.1 Outdoor Storage. For the prevention of fires with outdoor storage of biomass, see NFPA 46, *Recommended Safe Practice for Storage of Forest Products*.

7-5.3.2 Indoor Storage.

7-5.3.2.1 A communication system should be provided between facility personnel and the control room to expedite assistance in the event of fire.

7-5.3.2.2 For biomass materials subject to spontaneous ignition, the piles should be rotated on a regular basis.

7-5.3.2.3 Vehicles loaded with biomass should not be parked in the building or storage areas.

7-5.3.2.4 A regular program of housekeeping should be established to keep concentrations of combustible material to a minimum.

7-5.3.2.5 Operational experience has demonstrated that roving operators and other plant personnel have been key factors in detection of fires and unsafe conditions. It is important that they be properly trained to observe and react to incipient fire situations. These should be reported to the control room operator for evaluation to determine what action is to be taken.

7-5.3.2.6 The process should be designed to minimize the production of dust. Dust collected in a dust collection system, baghouse, or cyclone should be discharged downstream of the collection system, back to the conveying system, or back to the residue or waste stream. For additional guidance, see 5-4.3.4.

7-5.4 Fire Protection.

7-5.4.1 For the fire protection of outdoor biomass material, see NFPA 46, *Recommended Safe Practice for Storage of Forest Products*.

7-5.4.2 Hose stations designed in accordance with NFPA 14, *Standard for the Installation of Standpipe and Hose Systems*, should be located throughout the biomass storage, handling, and processing buildings. The following points should be considered:

(a) Location and physical protection so as to avoid potential damage due to traffic patterns.

(b) Size and number to be determined for unique plant geometry (e.g., push walls).

(c) Ease of use, maintenance, and storage, such as through the use of continuous-flow, noncollapsible hose reels.

(d) Protection from freezing in unheated areas.

NOTE: Based on plant geometry, combustible loading, and staff size, a 250-gpm (946 L/min) monitor nozzle may be needed in lieu of or in conjunction with hoses.

7-5.4.3 For biomass handling structures and conveyors, refer to 5-4.6.

NOTE: Conveyors can be considered protected by overhead sprinklers if not enclosed or hooded.

7-5.4.4 Biomass storage buildings should be provided with automatic sprinklers throughout. Systems should be designed for a minimum of 0.25 gpm/ft^2 (10.19 L/min-m^2) over the most remote 3000 ft^2 (279 m^2) (increase by 30 percent for dry pipe systems) of floor area with the protection area per sprinkler not to exceed 130 ft^2 (12.0 m^2).

NOTE: Biomass fuels exhibit a wide range of burning characteristics and upon evaluation can require increased levels of protection.

7-5.4.5 Based on the combustible loading, location, and essential use, an automatic sprinkler system should be considered for dust collectors, baghouses, and cyclone type separators. See 5-4.6.5.

7-5.4.6 Hydraulic equipment, reservoirs, coolers, and associated oil-filled equipment should be provided with automatic sprinkler or water spray protection. Sprinklers or spray nozzles should be over oil-containing equipment and for 20 ft (6.1 m) beyond in all directions. A density of 0.25 gpm/ft^2 (10.19 L/min-m^2) should be provided.

Exception: Where a listed fire-resistant fluid is used, protection is not needed.

7-5.5 Explosion Protection.

Biomass units utilizing equipment capable of producing explosive concentrations of gases or dusts as described in 7-5.2.3 should be provided with explosion venting or explosion suppression systems. For further guidance, see NFPA 68, *Guide for Venting of Deflagrations*, NFPA 69, *Standard on Explosion Prevention Systems*, and NFPA 664, *Standard for the Prevention of Fires and Explosions in Wood Processing and Woodworking Facilities*.

7-6 Rubber Tires.

7-6.1 General.

7-6.1.1 This section (Section 7-6) identifies fire and explosion hazards that are unique to the processing of rubber tires as a primary or secondary boiler fuel by means of a process that can include, but is not limited to, storing, shredding, and conveying the rubber tires to a fuel storage area (and conveying it from the storage area to fuel the boiler).

NOTE: In general, rubber tires have a Btu content of 15,000 Btu/lb; roughly two to three times that of wood or RDF.

7-6.1.2 There are several inherent fire hazards associated with scrap tires, whether outside or inside a building. Once tires are ignited, the fire develops rapidly, and it is difficult to extinguish. The tires will generate a large amount of black smoke. In addition, as the tires burn they generate oil that can spread and increase the size of the fire.

7-6.1.3 Hazards Associated with Scrap Rubber Tires. The major fire and explosion hazards associated with scrap rubber tire units are:

(a) Storage of large quantities of tires, whether inside or outside;

(b) Fast developing and rapidly spreading fire that burns for an extended period of time;

(c) Hampering of fire fighting due to the generation of large amounts of black smoke and water pollution from runoff;

(d) Unsuitable material entering the processing stream;

(e) Large amounts of scrap tires accumulating in unsuitable areas as a result of spillage, handling, and processing;

(f) Inadequate dust control.

7-6.2 Plant Arrangement.

7-6.2.1 The initial receiving and storage areas should be located outdoors. The area should be secured and cleared of all vegetation within 100 ft (30.5 m) of tire storage. See Appendix C of NFPA 231D, *Standard for Storage of Rubber Tires*, for further guidance on pile size, separation, and access.

7-6.2.2 The boiler feed equipment, such as a metering bin, should be of noncombustible material and designed to minimize pockets or corners that would cause combustible material to build up. Video monitoring should be considered for locations not readily visible to plant staff. Refer to NFPA 8501, *Standard for Single Burner Boiler Operation*; NFPA 8502, *Standard for the Prevention of Furnace Explosions/Implosions in Multiple Burner Boilers*; NFPA 8503, *Standard for Pulverized Fuel Systems*; NFPA 8504, *Standard on Atmospheric Fluidized-Bed Boiler Operation*; and NFPA 8505, *Recommended Practice for Stoker Operation*.

7-6.2.3* Where overhead cranes are used to load inside feed hoppers from inside the storage pits, the following should be considered:

(a) Locating the pulpit so that operator safety is not compromised.

(b) The ability to have a clear and unobstructed view of all storage and charging areas.

7-6.2.4 For tire plant processes that generate dust explosion potential, refer to NFPA 68, *Guide for Venting of Deflagrations*, NFPA 69, *Standard on Explosion Prevention Systems*, and individuals having specialized experience.

7-6.2.5 Smoke or heat vents should be considered in accordance with 3-4.1.

7-6.3 Prevention of Fires and Explosions in Scrap Rubber Tires.

7-6.3.1 A communication system should be provided between facility personnel and the control room to expedite assistance in the event of fire.

7-6.3.2 The facility personnel should ensure that scrap tires are continuously moved to the processing or storage areas. Vehicles loaded with scrap tires should not be parked in the building during idle periods.

7-6.3.3* A regular program of housekeeping should be established to keep concentrations of combustible material to a minimum.

7-6.3.4 The process should be designed to minimize the production of dust. Dust collected in a dust collection system, baghouse, or cyclone should be discharged downstream of the collection system, back to the conveying system, or back to the residue or waste stream. For additional guidance, see 5-4.3.4.

7-6.4 Fire Protection.

7-6.4.1 For the water supply and fire protection requirements of outdoor storage of scrap rubber tires, see Appendix C of NFPA 231D, *Standard for Storage of Rubber Tires.*

7-6.4.2 Hose stations designed in accordance with NFPA 14, *Standard for the Installation of Standpipe and Hose Systems*, should be located throughout the facility. The following points should be considered:

(a) Location and physical protection so as to avoid potential damage due to traffic patterns;

(b) Size and number to be determined for unique plant geometry (e.g., push walls);

(c) Protection from freezing in unheated areas;

NOTE 1: Hose stations are considered essential for final fire control and extinguishment. Addition of foam to hose streams should be considered.

NOTE 2: Plant geometry, combustible loading, and staffing may indicate that the use of 250 gpm monitor nozzles, in lieu of or in conjunction with hoses is acceptable.

7-6.4.3 Based upon the combustible loading, location, and essential use, an automatic sprinkler system should be considered for dust collectors, baghouses, and cyclone type separators. (*See 5-4.6.5*.)

7-6.4.4 For scrap rubber tire handling structures and conveyors, refer to 5-4.6.

NOTE: Experience indicates that sprinkler systems may not be effective and that foam-water spray systems are preferred for fire control. These systems are intended to confine the fire, and manual fire fighting may be required. Guidance should be sought from individuals having specialized experience for the selection of foam and foam application devices.

7-6.4.5 The scrap rubber tire pit should be provided with foam-water spray protection throughout. The system(s) should be designed for a minimum of 0.24 gpm/ft^2 (9.77 L/min-m^2) over the entire pit area with the protection area per nozzle not to exceed 100 ft^2 (9.3 m^2).

CAUTION: Due to the extreme hazard, clearance between the top of storage and foam-water spray systems should be minimized.

7-6.4.6 In addition to the foam-water spray protection, the storage pit should be provided with monitor nozzle protection designed to furnish a minimum of 250 gpm (946 L/min) at 100 psi (689 kPa) at the tip. Monitors should be located so as to allow for coverage of all pit areas with at least two streams operating simultaneously. Due to the potential for operator fire exposure, oscillating monitor nozzles with manual override should be provided.

NOTE: Addition of foam to the monitor nozzles should be considered.

7-6.4.7 For protection and storage of scrap rubber tires indoors, refer to NFPA 231D, *Standard for Storage of Rubber Tires*.

7-6.4.8 The boiler's tire feed system, including bins, hoppers, and chutes, should be considered for automatic foam-water protection. Where provided, the system should be designed for a minimum of 0.30 gpm/ft^2 (12.22 L/min-m^2) over the most remote 2500 ft^2 (232 m^2).

7-6.4.9 All water spray systems should be capable of remote actuation from the control room or other constantly attended areas. Additionally, local actuation stations should be placed adjacent to the fire areas along lines of egress and in consideration of operator safety and protection from damage due to equipment.

7-6.4.10 Hydraulic equipment, reservoirs, coolers, and associated oil-filled equipment should be provided with automatic sprinkler or water spray protection. Sprinklers or spray nozzles should be over oil-containing equipment and for 20 ft (6.1 m) beyond in all directions. A density of 0.25 gpm/ft^2 (10.19 L/min-m^2) should be provided.

Exception: Where a listed fire-resistant fluid is used, protection is not needed.

7-6.4.11 Particular care should be taken in the selection of detection devices in consideration of harsh and dusty environments and high air flows.

7-6.5 Explosion Protection.

Scrap rubber tire units utilizing equipment capable of producing explosive concentrations of gases or dusts should be provided with explosion venting or explosion suppression systems. For further guidance, see NFPA 68, *Guide for Venting of Deflagrations*, and NFPA 69, *Standard on Explosion Prevention Systems*.

7-7 Other Alternative Fuels and Processes.

Other alternative fuels (e.g., culm, peat, gob, etc.) are used as boiler fuels. Also, other technologies exist for the utilization and processing of alternative fuels as boiler fuels. It is recommended that designers seek guidance from those having specialized experience to understand the unique characteristics of any particular fuel or technology in order to properly apply the appropriate portions of this and other applicable documents.

Chapter 8 High Voltage Direct Current (HVDC) Converter Stations

8-1 General.

This chapter identifies the fire hazards of high voltage direct current (HVDC) converter stations and specifies recommended protection criteria.

8-2 Application of

Chapters 2 through 5 and Chapter 9. The recommendations contained in Chapters 2 through 5 and Chapter 9 may apply to high voltage direct current converter stations. It is incumbent upon the Fire Risk Evaluation to determine which recommendations apply to any specific HVDC converter station. This is done by evaluating the specific hazards that exist in the facility and determining the level of acceptable risk for the facility. It is expected that most of the recommendations will apply to all HVDC converter stations.

8-3 HVDC Converter Stations.

8-3.1 General.

8-3.1.1 This section (Section 8-3) identifies fire hazards that are associated with the operation of high voltage direct current converter stations. Conditions that could cause a fire in high voltage converter equipment include:

(a) loose electrical connections;

(b) electrical insulation or resistance breakdowns;

(c) overheated components;

(d) water leakage or intrusion (cooling system malfunction, roof leak, etc.); or

(e) foreign objects (tools, metal scrap, rubbish, vermin, etc.).

8-3.1.2 The hazards that could present a fire risk at a HVDC converter station include:

(a) Converter valve assemblies;

(b) Converter transformers;

(c) Oil-filled wall bushings;

(d) Capacitors containing combustible dielectric fluid or polymers; or

(e) Station services and auxiliary high voltage equipment.

8-3.2 Plant Arrangement.

8-3.2.1 Each thyristor valve hall should be established as a separate fire area. Each valve hall should be separated from adjacent fire areas by fire area boundaries in accordance with 3-1.1.3. Unless consideration of the factors of 3-1.1.2 indicates otherwise, it is recommended that fire area boundaries be provided to separate the following:

(a) service building;

(b) main control room;

(c) valve electronics rooms;

(d) HVAC equipment rooms; and

(e) relay room, SCADA room, and remote terminal unit room (RTU).

NOTE: If the Relay, SCADA, or RTU equipment is located in the main control room, fire partition barriers are not required for this equipment.

8-3.2.2 Converter valves and associated support equipment should use noncombustible or limited combustible materials. Where noncombustible or limited combustible materials are not used, fire-retardant separation barriers should be installed between the following equipment areas:

(a) valve tier levels, by adding to the bottom tray on each level;

(b) valve modules, by adding to the side of each tray section; and

(c) grading capacitors, snubber circuits, and power supplies.

8-3.2.3 Smoke or heat vents should be considered in accordance with 3-4.1.

8-3.2.4 Heating, ventilating, and air-conditioning (HVAC) systems for the valve hall should be provided with fire/smoke dampers arranged to shut down to preclude the entry of smoke from sources outside of the valve hall structure. A separate dedicated HVAC system should serve each valve hall.

8-3.2.5 Outdoor converter transformers and oil-filled smoothing reactor(s) should be arranged in accordance with 3-1.3 and 3-5.6.

8-3.2.6 Drainage provisions should be provided for indoor and outdoor oil-filled wall bushings. Drainage should be arranged in accordance with Section 3-5. Indoor oil-filled wall bushings should be provided with means to prevent the spread of oil to adjacent equipment. Where the converter bushings penetrate the valve hall, provisions should be made to prevent the oil contents of the transformer from entering the valve hall.

8-3.2.7 Mercury arc converters should be arranged to minimize the effects of a hazardous material spill or airborne contamination from mercury that could impede fire fighting efforts and restoration activities.

8-3.3 Fire Prevention.

8-3.3.1 An emergency communication system should be provided throughout the station to expedite assistance in the event of fire.

8-3.3.2 A fire emergency plan should be implemented in accordance with Section 2-7.

8-3.3.3 A regular housekeeping program should be established to maintain combustible and other materials in designated storage areas. Periodic cleaning of the valve and the valve hall structure should be performed in accordance with the manufacturer's instructions for maintaining a clean equipment and building environment.

8-3.3.4 Operational experience has demonstrated that operators and other plant personnel have been key factors in the detection of fires and unsafe conditions. It is important that all personnel be properly trained to observe and react appropriately to any potential fire situation.

NOTE: Control room operator fire emergency training should include, but not be limited to, the following:

(a) station emergency grounding procedures;

(b) valve hall clearance procedures;

(c) electrical equipment isolation; and

(d) timely communication of all fire events to the responding fire brigade and the fire department.

8-3.4 Fire Protection.

8-3.4.1 Hose stations designed in accordance with NFPA 14, *Standard for the Installation of Standpipe and Hose Systems*, should be located throughout the converter station.

8-3.4.2 Oil-filled wall bushings should be protected with automatic fire suppression system(s). The fire suppression system design should ensure that the fire suppression agent does not affect the converter valve, the arrestors, or other energized electrical equipment.

8-3.4.3 Auxiliary equipment areas and other structures should be protected with automatic protection systems in accordance with Sections 5-8 and 5-9. Converter transformers should be protected in accordance with 5-8.7.

8-3.4.4 The valve hall should be provided with an early warning multi-stage fire detection air sampling system capable of detecting an incipient fire such as an overheated component. Consideration should also be given to providing a second reliable fire detection system such as ionization, photo-electric, projected beam, optical devices, or video cameras. The interlock of a multi-stage smoke sampling system or the redundant fire detection system should be considered to initiate a fast-switch-off or emergency-switch-off of the respective valve group.

8-3.4.5 For the protection of the converter equipment and the building, water-based or gaseous agent suppression systems should be considered. The type and design of the suppression systems should be reviewed in consultation with the valve manufacturer.

8-3.4.6 To mitigate the effects of electrical shock and thermal impact involving the converter equipment, manual fire-fighting equipment utilization and deployment training should be provided for the fire brigade and responding fire department personnel.

Chapter 9 Fire Protection for the Construction Site

9-1 Introduction.

9-1.1

Although many of the activities on electric generating plant and HVDC converter station construction sites are similar to the construction of other large industrial plants, an above average level of fire protection is justified due to life safety consideration of the large number of on-site personnel, high value of materials, and length of the construction period. Consideration of fire protection should include safety to life, potential for delays in construction schedules and plant startup, as well as protection of property.

9-1.2

Major construction projects in existing plants present many of the hazards associated with new construction while presenting additional exposures to the existing facility. The availability of the existing plant fire protection equipment and the reduction of fire exposure by construction activities are particularly important.

9-1.3

For fire protection for plants and areas under construction, see NFPA 241, *Standard for Safeguarding Construction, Alteration, and Demolition Operations.* This chapter addresses concerns not specifically considered in NFPA 241.

9-2 Administration.

9-2.1

The responsibility for fire prevention and fire protection for the entire site during the construction period should be clearly defined. The administrative responsibilities should be to develop, implement, and periodically update as necessary the measures outlined in this recommended practice.

9-2.2

The responsibility for fire prevention and fire protection programs among various parties on site should be clearly delineated. The fire protection program that is to be followed and the owner's right to administration and enforcement should be established.

9-2.3

The fire prevention and fire protection program should include a Fire Risk Evaluation of the construction site and construction activities at any construction camp. (*See Chapter 2.*)

9-2.4

Written procedures should be established for the new construction site, including major construction projects in existing plants. Such procedures should be in accordance with Sections 2-4, 2-5, 2-6, 2-7, and 2-8.

9-2.5

Security guard service, including recorded rounds, should be provided through all areas of construction during times when construction activity is not in progress. (*See NFPA 601, Standard for Security Services in Fire Loss Prevention.*)

(a) The first round should be conducted one-half hour after the suspension of work for the day. Thereafter, rounds should be made every hour.

(b) Where partial construction activities occur on second and third shifts, the guard service rounds may be permitted to be modified to include only unattended or sparsely attended areas.

(c) In areas where automatic fire detection or extinguishing systems are in service, with alarm annunciation at a constantly attended location, or in areas of limited combustible loading, rounds may be permitted to be omitted after the first round indicated in (a) above.

9-2.6

Construction schedules should be coordinated so that planned permanent fire protection systems are installed and placed in service as soon as possible, at least prior to the introduction of any major fire hazards identified in Chapter 5.

9-2.7

In-service fire detection and fire extinguishing systems provide important protection for construction materials, storage, etc., even before the permanent hazard is present. Temporary fire protection systems may be warranted during certain construction phases. The need and type of protection should be determined by the individual responsible for fire prevention and fire protection.

9-2.8

Construction and installation of fire barriers and fire doors should be given priority in the construction schedule.

9-3 Site Clearing and Construction Equipment.

9-3.1 Site Clearing.

9-3.1.1 Prior to clearing forest and brush covered areas, the owner should ensure that a written fire control plan is prepared and that fire-fighting tools and equipment are made available as recommended by NFPA 295, *Standard for Wildfire Control*. Contact should be made with local fire and forest agencies for current data on restrictions and fire potential, and to arrange for necessary permits.

9-3.1.2 All construction vehicles and engine-driven portable equipment should be equipped with effective spark arrestors. Vehicles equipped with catalytic converters should be prohibited from wooded and heavily vegetated areas.

9-3.1.3 Fire tools and equipment should be used for fire emergencies only and should be distinctly marked.

9-3.1.4 Each site utility vehicle should be equipped with at least one fire-fighting tool, portable fire extinguisher, or backpack pump filled with 4 gal to 5 gal (15 L to 19 L) of water.

9-3.1.5 Cut trees, brush, and other combustible spoil should be disposed of promptly.

9-3.1.6 Where it is necessary to dispose of combustible waste by onsite burning, designated burning areas should be established with approval by the owner and should be in compliance with federal, state, and local regulations and guidelines. The contractor should coordinate burning with the agencies responsible for monitoring fire danger in the area and obtain all appropriate permits prior to the start of work. (*See Section 9-2.*)

9-3.1.7 Local conditions may require the establishment of fire breaks by clearing or use of selective herbicides in areas adjacent to property lines and access roads.

9-3.2 Construction Equipment.

Construction equipment should meet the requirements of NFPA 512, *Standard for Truck Fire Protection*.

9-4 Construction Warehouses, Shops, and Offices.

9-4.1

All structures that are to be retained as part of the completed plant should be constructed of materials as indicated in Chapter 3 and should be in accordance with other recommendations for the completed plant.

9-4.2

Construction warehouses, offices, trailers, sheds, and other facilities for the storage of tools and materials should be located with consideration of their exposure to major plant buildings or other important structures. (*For guidance in separation and protection, see NFPA 80A, Recommended Practice for Protection of Buildings from Exterior Fire Exposures*.)

9-4.3

Large central office facilities may be of substantial value and contain high value computer equipment, irreplaceable construction records, or other valuable contents, the loss of which may result in significant construction delays. An analysis of fire potential should be performed. This analysis may indicate a need for automatic sprinkler systems or other protection or the desirability of subdividing the complex to limit values exposed by one fire.

9-4.4

Warehouses that contain high value equipment (as defined by the individual responsible for fire prevention and fire protection), or where the loss of or damage to contents would cause a delay in startup dates of the completed plant, should be arranged and protected as indicated below. Although some of these structures are considered to be “temporary” and will be removed upon completion of the plant, the fire and loss potential should be thoroughly evaluated and protection provided where warranted.

9-4.4.1 Building construction materials should be noncombustible or limited combustible. (*See Chapter 3.*)

9-4.4.2 Automatic sprinkler systems should be designed and installed in accordance with the applicable NFPA standards. Waterflow alarms should be provided and located so as to be monitored at a constantly attended location as determined by the individual responsible for fire prevention and fire protection.

9-4.4.3 Air-supported structures sometimes are used to provide temporary warehousing space. Although the fabric envelope may be a fire-retardant material, the combustibility of contents and the values should be considered, as with any other type of warehouse. Because it is impractical to provide automatic sprinkler protection for them, air-supported structures should be used only for noncombustible storage. An additional factor to consider is that relatively minor fire damage to the fabric envelope may leave the contents exposed to the elements.

9-4.5

Temporary enclosures, including trailers, inside permanent plant buildings should be prohibited except where permitted by the individual responsible for fire prevention and fire protection. Where the floor area of a combustible enclosure exceeds 100 ft^2 (9.29 m^2) or where the occupancy presents a fire exposure, the enclosure should be protected with an approved automatic fire extinguishing system.

9-4.6

Storage of construction materials, equipment, or supplies that are either combustible or in combustible packaging should be prohibited in main plant buildings unless:

(a) An approved automatic fire extinguishing system is in service in the storage area, or

(b) Where loss of the materials or loss to the surrounding plant area would be minimal, as determined by the individual responsible for fire prevention and fire protection.

9-4.7

Construction camps comprised of mobile buildings arranged with the buildings adjoining each other to form one large fire area should be avoided. If buildings cannot be adequately separated, consideration should be given to installing fire walls between units or installing automatic sprinklers throughout the buildings.

9-4.8

Fire alarms should be connected to a constantly attended central location. All premise fire alarm systems should be installed, tested, and maintained as outlined in NFPA 72, *National Fire Alarm Code.*

9-4.9

The handling, storage, and dispensing of flammable liquids and gases should meet the requirements of NFPA 30, *Flammable and Combustible Liquids Code*; NFPA 58, *Standard for the Storage and Handling of Liquefied Petroleum Gases*; and NFPA 395, *Standard for the Storage of Flammable and Combustible Liquids at Farms and Isolated Sites*.

9-4.10

Vehicle repair facilities should meet the requirements of NFPA 88B, *Standard for Repair Garages*.

9-5 Construction Site Lay-Down Areas.

9-5.1

Fire hydrant systems with an adequate water supply should be provided in lay-down areas where the need is determined by the individual responsible for fire prevention and fire protection.

9-5.2

Combustible materials should be separated by a clear space to allow access for manual fire-fighting equipment (*see Section 9-8*). Access should be provided and maintained to all fire-fighting equipment including fire hoses, extinguishers, and hydrants.

9-6 Temporary Construction Materials.

9-6.1

Noncombustible or fire-retardant scaffolds, form work, decking, and partitions should be used both inside and outside of permanent buildings where a fire could cause substantial damage or delay construction schedules.

9-6.1.1 The use of noncombustible or fire-retardant concrete form work is especially important for large structures (e.g., turbine-generator pedestal) where large quantities of forms are used.

9-6.1.2 The use of listed pressure-impregnated fire-retardant lumber or listed fire-retardant coatings generally would be acceptable. Pressure-impregnated fire-retardant lumber should be used in accordance with its listing and manufacturer's instructions. Where exposed to the weather or moisture (e.g., concrete forms), the fire retardant used should be suitable for this exposure. Fire-retardant coatings are not acceptable on walking surfaces or surfaces subject to mechanical damage.

9-6.2

Tarpaulins and plastic films should be of listed weather-resistant and fire-retardant materials. (*See NFPA 701*, *Standard Methods of Fire Tests for Flame-Resistant Textiles and Films*.)

9-7 Underground Mains, Hydrants, and Water Supplies.

9-7.1 General.

9-7.1.1 Where practical, the permanent underground yard system, fire hydrants, and water supply (at least one water source), as indicated in Chapter 4, should be installed during the early stages of construction. Where provision of all or part of the permanent underground system and water supply is not practical, temporary systems should be provided. Temporary water supplies should be hydrostatically tested, flushed, and arranged to maintain a high degree of reliability, including protection from freezing and loss of power.

9-7.1.2 The necessary reliability of construction water supplies, including redundant pumps, arrangement of power supplies, and use of combination service water and construction fire protection water, should be determined by the individual responsible for fire prevention and fire protection.

9-7.2

Hydrants should be installed, as indicated in Chapter 4, in the vicinity of main plant buildings, important warehouses, office or storage trailer complexes, and important outside structures with combustible construction or combustible concrete form work (e.g., cooling towers). Where practical, the underground main should be arranged to minimize the possibility that any one break will remove from service any fixed water extinguishing system or leave any area without accessible hydrant protection.

9-7.3

A fire protection water supply should be provided on the construction site and should be capable of furnishing the largest of the following for a minimum 2-hour duration:

(a) 750 gpm (47.3 L/sec), or

(b) The in-service fixed water extinguishing system with the highest water demand and 500 gpm (31.5 L/sec) for hose streams.

9-7.3.1 The highest water demand should be determined by the hazards present at the stage of construction, which might not correspond with the highest water demand of the completed plant.

9-7.3.2 As fixed water extinguishing systems are completed, they should be placed in service, even when the available construction phase fire protection water supply is not adequate to meet the system design demand. The extinguishing system will at least provide some degree of protection, especially where the full hazard is not yet present. However, when the permanent hazard is introduced, the water supply should be capable of providing the designed system demand. When using construction water in permanent systems, adequate strainers should be provided to prevent clogging of the system by foreign objects and dirt.

9-7.3.3 The water supply should be sufficient to provide adequate pressure for hose connections at the highest elevation.

9-8 Manual Fire Fighting Equipment.

9-8.1

First aid fire-fighting equipment should be provided, in accordance with NFPA 600, *Standard on Industrial Fire Brigades* and NFPA 241, *Standard for Safeguarding Construction, Alteration, and Demolition Operations*.

NOTE: Mobile fire-fighting equipment can be utilized to provide necessary first aid fire-fighting equipment.

9-8.2

Portable fire extinguishers of suitable capacity should be provided in accordance with NFPA 10, *Standard for Portable Fire Extinguishers*, where:

(a) Flammable liquids are stored or handled,

(b) Combustible materials are stored,

(c) Temporary oil- or gas-fired equipment is used,

(d) A tar or asphalt kettle is used, or

(e) Welding or open flames are in use.

9-8.3

Hoses and nozzles should be available at strategic locations, such as inside hose cabinets or hose houses or on dedicated fire response vehicles.

9-8.4

If fire hose connections are not compatible with local fire-fighting equipment, adapters should be made available.

Chapter 10 Referenced Publications

10-1

The following documents or portions thereof are referenced within this recommended practice and should be considered part of the recommendations of this document. The edition indicated for each reference is the current edition as of the date of the NFPA issuance of this document.

10-1.1 NFPA Publications.

National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.

NFPA 10, *Standard for Portable Fire Extinguishers*, 1994 edition.

NFPA 11, *Standard for Low-Expansion Foam*, 1994 edition.

NFPA 11A, *Standard for Medium- and High-Expansion Foam Systems,* 1994 edition.

NFPA 11C, *Standard for Mobile Foam Apparatus*, 1995 edition.

NFPA 12, *Standard on Carbon Dioxide Extinguishing Systems*, 1993 edition.

NFPA 12A, *Standard on Halon 1301 Fire Extinguishing Systems*, 1992 edition.

NFPA 13, *Standard for the Installation of Sprinkler Systems*, 1994 edition.

NFPA 14, *Standard for the Installation of Standpipe and Hose Systems*, 1996 edition.

NFPA 15, *Standard for Water Spray Fixed Systems for Fire Protection*, 1990 edition.

NFPA 16, *Standard for the Installation of Deluge Foam-Water Sprinkler and Foam-Water Spray Systems*, 1995 edition.

NFPA 16A, *Standard for the Installation of Closed-Head Foam-Water Sprinkler Systems*, 1994 edition.

NFPA 17, *Standard for Dry Chemical Extinguishing Systems*, 1994 edition.

NFPA 20, *Standard for the Installation of Centrifugal Fire Pumps*, 1993 edition.

NFPA 22, *Standard for Water Tanks for Private Fire Protection*, 1996 edition.

NFPA 24, *Standard for the Installation of Private Fire Service Mains and Their Appurtenances*, 1995 edition.

NFPA 30, *Flammable and Combustible Liquids Code*, 1993 edition.

NFPA 31, *Standard for the Installation of Oil-Burning Equipment*, 1992 edition.

NFPA 37, *Standard for the Installation and Use of Stationary Combustion Engines and Gas Turbines*, 1994 edition.

NFPA 46, *Recommended Safe Practice for Storage of Forest Products*, 1996 edition.

NFPA 50A, *Standard for Gaseous Hydrogen Systems at Consumer Sites*, 1994 edition.

NFPA 50B, *Standard for Liquefied Hydrogen Systems at Consumer Sites*, 1994 edition.

NFPA 51B, *Standard for Fire Prevention in Use of Cutting and Welding Processes*, 1994 edition.

NFPA 54, *National Fuel Gas Code*, 1992 edition.

NFPA 58, *Standard for the Storage and Handling of Liquefied Petroleum Gases*, 1995 edition.

NFPA 61, *Standard for the Prevention of Fires and Dust Explosions in Agricultural and Food Products Facilities*, 1995 edition.

NFPA 68, *Guide for Venting of Deflagrations*, 1994 edition.

NFPA 69, *Standard on Explosion Prevention Systems*, 1992 edition.

NFPA 70, *National Electrical Code*, 1996 edition.

NFPA 72, *National Fire Alarm Code*, 1993 edition.

NFPA 75, *Standard for the Protection of Electronic Computer/Data Processing Equipment*, 1995 edition.

NFPA 77, *Recommended Practice on Static Electricity*, 1993 edition.

NFPA 80, *Standard for Fire Doors and Fire Windows*, 1995 edition.

NFPA 80A, *Recommended Practice for Protection of Buildings from Exterior Fire Exposures*, 1993 edition.

NFPA 88B, *Standard for Repair Garages*, 1991 edition.

NFPA 90A, *Standard for the Installation of Air Conditioning and Ventilating Systems*, 1993 edition.

NFPA 90B, *Standard for the Installation of Warm Air Heating and Air Conditioning Systems*, 1993 edition.

NFPA 91, *Standard for Exhaust Systems for Air Conveying of Materials*, 1995 edition.

NFPA 92A, *Recommended Practice for Smoke-Control Systems*, 1993 edition.

NFPA *101*, *Life Safety Code*, 1994 edition.

NFPA 204M, *Guide for Smoke and Heat Venting*, 1991 edition.

NFPA 214, *Standard on Water-Cooling Towers*, 1992 edition.

NFPA 220, *Standard on Types of Building Construction*, 1995 edition.

NFPA 231, *Standard for General Storage*, 1995 edition.

NFPA 231C, *Standard for Rack Storage of Materials*, 1995 edition.

NFPA 231D, *Standard for Storage of Rubber Tires*, 1994 edition.

NFPA 241, *Standard for Safeguarding Construction, Alteration, and Demolition Operations*, 1993 edition.

NFPA 251, *Standard Methods of Tests of Fire Endurance of Building Construction and Materials*, 1995 edition.

NFPA 252, *Standard Methods of Fire Tests of Door Assemblies*, 1995 edition.

NFPA 253, *Standard Method of Test for Critical Radiant Flux of Floor Covering Systems Using a Radiant Heat Energy Source*, 1995 edition.

NFPA 255, *Standard Method of Test of Surface Burning Characteristics of Building Materials*, 1996 edition.

NFPA 256, *Standard Methods of Fire Tests of Roof Coverings*, 1993 edition.

NFPA 257, *Standard on Fire Test for Window and Glass Block Assemblies*, 1996 edition.

NFPA 259, *Standard Test Method for Potential Heat of Building Materials*, 1993 edition.

NFPA 295, *Standard for Wildfire Control*, 1991 edition.

NFPA 299, *Standard for Protection of Life and Property from Wildfire*, 1991 edition.

NFPA 395, *Standard for the Storage of Flammable and Combustible Liquids at Farms and Isolated Sites*, 1993 edition.

NFPA 512, *Standard for Truck Fire Protection*, 1994 edition.

NFPA 600, *Standard on Industrial Fire Brigades*, 1996 edition.

NFPA 601, *Standard for Security Services in Fire Loss Prevention*, 1996 edition.

NFPA 664, *Standard for the Prevention of Fires and Explosions in Wood Processing and Woodworking Facilities*, 1993 edition.

NFPA 701, *Standard Methods of Fire Tests for Flame-Resistant Textiles and Films*, 1996 edition.

NFPA 704, *Standard System for the Identification of the Fire Hazards of Materials*, 1990 edition.

NFPA 780, *Standard for the Installation of Lightning Protection Systems*, 1995 edition.

NFPA 803, *Standard for Fire Protection for Light Water Nuclear Power Plants*, 1993 edition.

NFPA 851, *Recommended Practice for Fire Protection for Hydroelectric Generating Plants,* 1996 edition.

NFPA 1221, *Standard for the Installation, Maintenance, and Use of Public Fire Service Communication Systems*, 1994 edition.

NFPA 1962, *Standard for the Care, Use, and Service Testing of Fire Hose Including Couplings and Nozzles*, 1993 edition.

NFPA 1972, *Standard on Helmets for Structural Fire Fighting*, 1992 edition.

NFPA 8501, *Standard for Single Burner Boiler Operation*, 1992 edition.

NFPA 8502, *Standard for the Prevention of Furnace Explosions/Implosions in Multiple Burner Boilers*, 1995 edition.

NFPA 8503, *Standard for Pulverized Fuel Systems*, 1992 edition.

NFPA 8504, *Standard on Atmospheric Fluidized-Bed Boiler Operation*, 1993 edition.

NFPA 8505, *Recommended Practice for Stoker Operation*, 1992 edition.

10-1.2 Other Publications.

10-1.2.1 ANSI Publications. American National Standards Institute Inc., 1450 Broadway, New York, NY 10018.

ANSI A14.3, *Standard for Safety Requirements for Fixed Ladders*, 1984.

ANSI A1264.1, *Safety Requirements for Workplace Floor and Well Openings, Stairs, and Railing Systems*.

ANSI B133.4, *Gas Turbine Control and Protection Systems*, 1978.

ANSI B31.1, *Code for Power Piping*, 1989.

ANSI C2, *National Electrical Safety Code*, 1981.

ANSI Z210.1, *Metric Practice Guide*, 1993.

10-1.2.2 ASTM Publications. American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19105.

ASTM E 136, *Standard Test Method for Behavior of Materials in a Vertical Tube Furnace at 750°C*, 1994.

ASTM E 380 (*see ANSI Z210.1*), 1993.

ASTM E 814, *Fire Tests of Through-Penetration Fire Stops*, 1994.

10-1.2.3 IEEE Publications. Institute of Electrical and Electronics Engineers, 345 East 47 St., New York, NY 10070.

IEEE 383, *Standard for Type Test of Class IE Electric Cables, Field Splices and Connections for Nuclear Power Generating Stations*, 1974.

IEEE 484, *Recommended Practice for Installation Design and Installation of Large Lead Storage Batteries for Generating Stations and Substations*, 1987.

IEEE 634, *Testing of Fire Rated Penetration Seals*, 1978.

IEEE 979, *Guide for Substation Fire Protection*, 1994.

10-1.2.4 OSHA Publication. Occupational Safety and Health Administration, Washington, DC.

29 CFR 1910.156, Fire Brigades, 1986.

10-1.2.5 EPRI Publication. Electric Power Research Institute, 3412 Hillview Avenue, P.O. Box 10412, Palo Alto, CA 94303.

EPRI Research Project 1843-2, *Turbine Generator Fire Protection by Sprinkler System*, July 1985.

10-1.2.6 UL Publication. Underwriters Laboratories Inc., 333 Pfingsten Road, Northbrook, IL 60062.

UL 900, *Standard for Safety Test Performance of Air Filters*, 1987.

10-2 Related Publications.

10-2.1 ANSI Publications.

American National Standards Institute Inc., 1450 Broadway, New York, NY 10018.

ANSI B133.3, *Procurement Standard for Gas Turbine Auxiliary Equipment*, 1981.

ANSI B133.4, *Gas Turbine Control and Protection Systems*, 1978.

ANSI B133.5, *Procurement Standard for Gas Turbine Electrical Equipment*, 1978.

ANSI/ASME B133.7M, *Gas Turbine Fuels*, 1985.

ANSI B133.10, *Procurement Standard for Gas Turbine Information to be Supplied by User or Manufacturer*, 1981.

ANSI B133.11, *Procurement Standard for Gas Turbine Preparation for Shipping and Installation*, 1982.

ANSI B133.12, *Procurement Standard for Gas Turbine Maintenance and Safety*, 1981.

Appendix A Explanatory Material

This Appendix is not a part of the requirements of this NFPA document but is included for informational purposes only.

A-1-4 Approved.

The National Fire Protection Association does not approve, inspect, or certify any installations, procedures, equipment, or materials; nor does it approve or evaluate testing laboratories. In determining the acceptability of installations, procedures, equipment, or materials, the authority having jurisdiction may base acceptance on compliance with NFPA or other appropriate standards. In the absence of such standards, said authority may require evidence of proper installation, procedure, or use. The authority having jurisdiction may also refer to the listings or labeling practices of an organization concerned with product evaluations that is in a position to determine compliance with appropriate standards for the current production of listed items.

A-1-4 Authority Having Jurisdiction.

The phrase "authority having jurisdiction" is used in NFPA documents in a broad manner, since jurisdictions and approval agencies vary, as do their responsibilities. Where public safety is primary, the authority having jurisdiction may be a federal, state, local, or other regional department or individual such as a fire chief; fire marshal; chief of a fire prevention bureau, labor department, or health department; building official; electrical inspector; or others having statutory authority. For insurance purposes, an insurance inspection department, rating bureau, or other insurance company representative may be the authority having jurisdiction. In many circumstances, the property owner or his or her designated agent assumes the role of the authority having jurisdiction; at government installations, the commanding officer or departmental official may be the authority having jurisdiction.

A-1-4 Listed.

The means for identifying listed equipment may vary for each organization concerned with product evaluation, some of which do not recognize equipment as listed unless it is also labeled. The authority having jurisdiction should utilize the system employed by the listing organization to identify a listed product.

A-2-8.2

Recommendations contained in NFPA 600, *Standard on Industrial Fire Brigades,* and 29 CFR 1910, Subparts E and L should be consulted for additional information.

A-5-4.2.1 Spontaneous Heating. The chemical properties of coals that effect spontaneous combustion are oxygen content, moisture, impurities (especially sulfur in the form of pyrites), and volatiles. The physical properties are particle size and friability.

Spontaneous heating occurs due to oxidation of freshly exposed coal surfaces. For spontaneous heating to lead to ignition sufficient air must be present and in contact with fresh (unoxidized) surfaces, yet without sufficient air movement to dissipate heat generated by oxidation. The oxidation rate of coal at ambient temperatures is determined by its rank, its exposed surface area and the percentage of free oxygen in the atmosphere permeating the coal. Coal of low rank (soft coal) will have a higher oxidation rate than harder coal under the same conditions. Likewise, if coal is crushed to a finer particle size, more surface area will be exposed and the oxidation rate will increase. A reduction in free oxygen content in the atmosphere permeating the coal reduces the rate of oxidation (almost proportionately). Oxidation will continue at a reduced rate until the free oxygen is exhausted. Heat produced by spontaneous combustion will be absorbed by the coal resulting in an increase in coal temperature. Due to the chimney effect, air infiltration leakage might be expected around the discharge valve or other bottom leaks of silos and bunkers or in the top 5 ft to 6 ft (1.5 m to 1.8 m) of the coal in the bunker. Therefore “hot spots” will tend to develop in the lower and upper portions of the coal in the silo and near any seams or openings that allow air infiltration. Inerting the coal with carbon dioxide or nitrogen, and covering the top of the bunker to prevent air to cause spontaneous ignition is a common practice for forced and extended outage with coal in the bunker. As the coal temperature increases the rate of oxidation will also increase. Due to the range and number of variables it is difficult to define the time to ignition of coal in storage.

Spontaneous heating can be mitigated by minimizing wetting of the coal, the duration of storage of the coal, and air movement in the silo.

A-5-4.2.2 Silo Construction. If the plant is designed to burn a type of coal that is considered prone to spontaneous combustion or one that has a high percentage of “volatiles,” silos should be cylindrical with conical hoppers. The coal’s angle of repose should be considered when designing the internal slope of the silo and hopper so that coal will flow freely (normally 60 degrees from the horizontal will be sufficient) to avoid arching and voiding. Air cannons located at the throat of the silo can be used to ensure that coal continues to flow, however, caution is necessary to ensure that air cannons are not utilized during a fire or where low coal levels could result in suspended coal dust entering the explosive range.

Experience indicates that coal volatility content above 38 percent might be conducive to spontaneous heating. The designer might consider inerting the silo if the volatiles content of the coal exceeds 38 percent. Where the coal used has known spontaneous heating problems, special conveyors and chutes or pans can be provided to unload silos during forced outages.

A-5-4.2.3 Silo Operations and Maintenance. Where possible, coal silos should be operated at full capacity and coal should flow continuously. When silos are not operated at or near full volume spontaneous combustion may occur at an increased rate. These conditions should be monitored periodically. Daily carbon monoxide samples should be taken at the top of each silo to establish a benchmark carbon monoxide level. Increased carbon monoxide levels can give an early indication of a hot spot or silo fire. Some experience in this area indicates that the carbon monoxide levels may rise days before fires are detected by other means. Silo should be run empty and inspected if the carbon monoxide levels exceed twice the benchmark concentration.

Dependent on bin, bunker, or silo construction, the internal space might allow the build-up of coal on its walls. Removing the coal from the bin, bunker, or silo wall can be employed to minimize the risk of spontaneous combustion of the trapped coal.

During planned maintenance outages, silos should be emptied and thoroughly cleaned of coal deposits. Operating procedures should ensure that magnetic separators are in service when coal is being conveyed into the silo to avoid introducing tramp metals. Movement of tramp metal within the silo can result in an ignition source by striking metal parts causing sparks that might ignite coal dust.

Three fires involving coal silos at one operating electric generating station occurred at or near cracks in the bottom cone of the silo. During maintenance outages the cones should be thoroughly inspected for cracks.

A long thermocouple [i.e., 10 ft (3 m)] connected to a portable instantaneous readout monitor can be employed. Pushing the thermocouple into the coal storage can detect developing hot areas or strata at different depths. Periodic monitoring of temperature change in these areas will help predict spontaneous combustion development and aid in response preplanning. Portable infrared heat detection or thermography has also proven useful in locating hot spots. Typical hot spots are easily detected when they are in the size range of 2 ft (0.6 m) in diameter. Hot spots in the center and higher up may not be found until the hot spot enters the cone area as the coal level drops.

A-5-4.2.6 Manual Fire Suppression. Fire fighting in coal silos is a long and difficult activity. Some fire-fighting operations have taken several days to completely extinguish a fire.

Smoldering coal in a coal bin, bunker, or silo is a potentially dangerous situation that depends on the location of the smoldering coal. There is a risk of a flash fire or explosion if the smoldering coal is disturbed. This risk should be considered in preplanning. Personnel responding to a coal fire should have proper personal protective equipment, including SCBA and turnout gear, and training in this hazard.

The area surrounding the smoldering coal should also be considered. The potential of developing an immediately dangerous to life and health (IDLH) atmosphere is possible. This should also be considered in preplanning.

Depending on the strategy selected, resource demands will be varied but challenging. Prefire planning is an important element in successful silo fire control and should be included in the initial plant Fire Risk Evaluation (*see Section 2-3*) and the Fire Emergency Plan (*see Section 2-7*). Control room operators should be involved with the preplanning.

Use of Class A Foams and Penetrants. Use of Class A foams and penetrants have found some success but it has been difficult to predict the resources required for successful fire control. The agents generally require mixing with water prior to application, usually in the range of 1 percent by volume, mixed in a manner similar to Class B agents. While the typical application of Class A foam is to fight wildland fires at 1 percent, many plants have reported success with using Class A foams at 0.1 percent. This causes the agent to act as a surfactant. Higher proportions have caused excessive bubble accumulation that impedes penetration into the coal.

The application of foams and penetrants can be enhanced by using an infrared camera to search for hot spots, either on the sides or top of the silo, to facilitate injection of the agent as close as possible to the fire area. The infrared imagery can be used to evaluate performance and monitor progress of the attack. The water/agent solution must penetrate to the seat of combustion to be effective. This can be affected by the degree of compaction, voids, rate of application, evaporation rate, etc. Run-off must be drained through feeder pipe and will require collection, clean-up, and disposal.

Use of Inerting Gas. Carbon dioxide and nitrogen have been used successfully as gaseous inerting agents.

Carbon dioxide vapor has proven to be an effective fire suppression agent when forced through the coal by pressure injection in the lower part of the silo. The rate of application should be sufficient to compensate for limited losses at the coal valve and for absorption by the coal.

Inerting can normally be initiated within an eight hour shift if a supply of carbon dioxide is available.

Since carbon dioxide is stored as a liquid, it must be vaporized before injection into the silo. This is accomplished using an external, in-line vaporizer sized such that the anticipated application rate can be increased if the maximum anticipated leakage rate is exceeded.

Normal inerting procedure involves starting the carbon dioxide flow at a pre-set volume from the flow control valve. The system pipe should be grounded to prevent a static spark potentially igniting a flammable vapor concentration. Initially, the carbon dioxide vapor should be injected into the space above the coal at the top of the silo to mitigate the potential of developing an explosive atmosphere. Once this inerting is established, the flow can be reduced and the primary flow directed into the bottom (while continuing trickle injection into the top) of the silo. Silo geometry is conducive to establishing a chimney affect that will prevent the carbon dioxide from settling throughout the silo. Therefore it is necessary to add injection points near the bottom.

Experience indicates that carbon dioxide inerting is considered successful when the carbon dioxide concentration reaches 65 percent. However, the logistics of injecting carbon dioxide might result in almost 100 percent saturation throughout most of the silo in order to achieve at least 65 percent concentration in all portions of the silo. Since leakage in the silo is inevitable, it will be necessary to anticipate using a large quantity of carbon dioxide. Experience at one utility suggests that it is advisable to order a quantity of carbon dioxide equivalent to about 3 times the gross volume of the silo. If liquid carbon dioxide cylinders are used, an additional quantity will be necessary since only about 70 percent of the cylinder's contents can be extracted as a vapor.

The following is an example of calculating the quantity of carbon dioxide. If a silo is 30,000 ft^3 and low pressure carbon dioxide is used:

- 30,000 $ft^3 \times 3$ (times the gross volume) = 90,000 ft^3 of carbon dioxide.
- 90,000 ft^3 of carbon dioxide / 8.3 ft^3/lb of carbon dioxide = 10,843 lb (or about 5.5 tons).

The carbon dioxide storage system should be arranged so that it can be replenished during operation in the event that the fire is embedded, which could cause extinguishment to be delayed for a matter of days.

When carbon dioxide is used, there is a risk of oxygen depletion in the area above, around, or below a silo, bin, or bunker. Areas where gas could collect and deplete oxygen should be identified with appropriate barriers and warning signs. This might include the tripper room and areas below the discharge feeder gate.

Nitrogen has been used successfully to inert silo fires. It is applied in a manner very similar to carbon dioxide. A notable difference is that nitrogen has about the same density as air (whereas carbon dioxide is significantly more dense.) Therefore it must be applied at numerous injection points around the silo to ensure that it displaces available oxygen. This results in the need for more injection equipment and a larger quantity of agent.

Emptying the Silo. The silo can be unloaded through the feeder pipe but it is a dirty, messy operation. It is necessary to bypass the feeder belt and to dump the coal onto the floor of the power house at the feeder elevation. A hose crew should be available to extinguish burning coal as it is discharged from the silo. There is a risk that dust raised during this activity can ignite explosively. High expansion foam can be applied.

Carbon monoxide produced during the combustion process will also tend to settle in the lower elevation and can be a hazard to the hose crew. Once spilled and extinguished, it is usually necessary to shovel the coal into a dump truck for transport back to the coal pile.

Manual Fire Fighting. Regardless of the type of suppression approach selected, prefire planning is an important element of successful fire control and extinguishment. All necessary resources should be identified and in place prior to beginning fire suppression activities. If necessary materials are not stockpiled onsite, suppliers should be contacted in advance to ensure that equipment and supplies are available on relatively short notice.

The personnel requirements for this fire-fighting activity should be identified in advance. Personnel should be trained and qualified for fire fighting in the hot, smoky environment that might accompany a silo fire. This includes the use of self-contained breathing apparatus and personal protective equipment. Personnel engaged in this activity should be minimally trained and equipped to the structural fire brigade level as defined in NFPA 600, *Standard on Industrial Fire Brigades*. If station personnel are not trained in use of self-contained breathing apparatus, it will be necessary for the public fire department to perform fire-fighting in these areas. Station personnel are still needed to assist with operational advice and guidance. The public fire-fighting agency that responds to a fire at the facility should be involved in preplanning fire-fighting activities for silo fires. The public fire service might need specific instruction concerning operation and potential hazards associated with coal silo fires as well as operation in the power plant environment. It is important that the responding fire service be supplied information and guidance at every opportunity.

The resources of the station and the local fire service need to work in concert, including working with control room operators and keeping them apprised of fire control operations. Preplanning should include administrative details such as chain of command, access, etc. Operations should be coordinated by an established incident command system in conformance with NFPA 1561, *Standard on Fire Department Incident Command System*. All personnel should be familiar with and practice this system prior to the event.

A-5-4.3 Coal Dust Hazards.

The hazard of any given coal dust is related to the ease of ignition and the severity of the ensuing explosion. The Bureau of Mines of the U.S. Department of Interior has developed an arbitrary scale, based on small scale tests, that is quite useful for measuring the potential explosion hazard of various coal dusts. The ignition sensitivity is a function of the ignition temperature and the minimum energy of ignition, whereas the explosivity is based on data developed at the Bureau of Mines. The test results are based on a standard Pittsburgh coal dust taken at a concentration of 0.5 ounces per cubic foot. The Explosibility Index is the product of ignition sensitivity and explosion severity. This method permits evaluation of relative hazards of various coal dusts.

When coal silos are operated with low inventory there is potential for suspended coal dust to enter the explosive range. As in spontaneous heating, the explosive range and potential for explosion are based on the above variables.

A-5-6.5 Scrubber Fire Loss Experience.

There have been at least three major fires involving scrubbers with plastic lining or plastic fill. They have the following factors in common:

(a) Fire occurred during an outage;

(b) Fire was detected immediately;

(c) Fire was caused by cutting and welding;

(d) Rapid fire spread prevented access to the interior of the scrubber which made manual fire fighting ineffective.

The following are brief summaries of the losses reported to date:

Fire No. 1. The scrubber was 36 ft (11 m) in diameter and 139 ft (42 m) high. The scrubber contained two sections of polypropylene packing: one section was 4 ft (1.2 m) thick and one section was 3 ft (1 m) thick. The 3 ft (1 m) thick section was removed at the time of the fire. Both layers of packing extended across the full diameter of the tower. An outside contractor was making repairs on a turning vane at the top of the scrubber. A welding blanket had been placed over the top of the fill. Sparks from the welding operation fell through the wood work platform and ignited the polypropylene packing 30 ft (9 m) below. The fire was detected immediately. Plant employees reacted rapidly and followed procedures established in advance. They actuated the demister spray nozzles, then closed access doors and the outlet damper to isolate the scrubber. Plant employees used $1^1/_2$ in. (3.8 cm) hose on the outside of the duct. The public fire department responded. Total fire duration was two minutes. Property damage was estimated at $5,000,000, the outage was 41 days.

Fire No. 2. There were four scrubbers in one building. The scrubbers were 30 ft × 30 ft × 80 ft (9 m × 9 m × 24 m) high. The scrubbers have an extensive amount of plastic packing and are lined. Maintenance was being performed on one of the scrubbers. A crew planned to make repairs to the liner near the top of the scrubber. The repair work involved cutting and welding operations. Hot metal fell down inside the scrubber. A small fire was observed in the lower part of the scrubber which quickly spread and burned out the lining and packing. Fire burned through the expansion joint on the top of the scrubber and spread throughout the penthouse with damage to building structural steel in the area above the scrubber. Property damage was estimated at $7,000,000, the outage was about eight months. This was due to the need for the replacement of the shell.

Fire No. 3. There were three absorber towers in one building. The towers were 40 ft × 65 ft × 185 ft (12.1 m × 19.7 m × 56 m) high. The scrubbers were lined with a rubber coating and had polypropylene mist eliminators. Workers were in the exhaust duct of one of the scrubbers attempting to seal small holes in the duct. Plastic sheeting was used to protect an expansion joint. Sparks from the welding operation ignited the plastic. Fire was detected immediately. Portable extinguishers were used to fight the fire. The fire quickly spread to wood scaffolding. The plant fire brigade responded but could not enter the duct due to dense smoke. Fire spread to the polypropylene mist eliminator and the rubber lining in the scrubber. Heat from the fire vented into the building collapsing the roof. The scrubber was destroyed. Property damage was estimated at $42,000,000. The station was under construction and its completion was delayed two years by the fire.

A-5-8.7

For information pertaining to fire protection guidelines for substations, see ANSI/IEEE 979, *Guide for Substation Fire Protection*.

A-7-6.2.3 For additional guidance on cranes and storage pits, refer to 7-4.2.

A-7-6.3.3 For additional guidance, see Appendix C of NFPA 231D, *Standard for Storage of Rubber Tires*.

Appendix B Sample Fire Report

This Appendix is not a part of the recommendations of this NFPA document but is included for informational purposes only.

Name of company: ____

Date of fire: ____ Time of fire: ____________ Operating facility: ________________

Under construction: ____

Plant or location where fire occurred: ___________________________________

Description of facility, fire area, or equipment (include nameplate rating) involved:

____

Cause of fire, such as probable ignition source, initial contributing fuel, equipment failure causing ignition, etc.:

____

____

____

Story of fire, events, and conditions preceding, during, and after the fire:

____

____

____

Types and approximate quantities of portable extinguishing equipment used:

____

____

Was fire extinguished with portable equipment only? ________________________________

Public fire department called? ________ Employee fire brigade at this location? __________

Qualified for incipient fires? __________ For interior structural fires? __________________

Was fixed fire extinguishing equipment installed?____________________________________

Type of fixed extinguishing system: ____ ____

Automatic operation: ________ , manually actuated:__________ , or both: ____________

Specific type of detection devices: ____

Did fixed extinguishing system control? ____________ and/or extinguish fire? ________

Did detection devices and extinguishing system function properly? ______________________

If "no," why not? ____

____

Estimated direct damage due to fire: $ ______________ , or between $ ________and $ __

Estimated additional (consequential) loss: $ ____________ Nature of additional loss: ____

____

____

Estimated time to complete repairs/replacement of damaged equipment/structure:

____

Number of persons injured: ________________________ Number of fatalities: ________

What corrective or preventive suggestions would you offer to other utilities who may have similar equipment, structures, or extinguishing systems? ______________________________

____

____

Submitted by: ____________________________________ Title:______________________

Appendix C Fire Tests

This Appendix is not a part of the recommendations of this NFPA document but is included for informational purposes only.

NOTE: Footnotes refer to reference list numbers at end of Appendix C.

This Appendix summarizes the results of fire tests in which automatic sprinklers or water spray systems were used to extinguish or control fires in oil and grouped cables. Also included in this Appendix are results of tests conducted on fiberglass stack liners.

C-1 Combustible Oil Fire Tests.

C-1.1 General.

Oils (except for crude oil) handled in bulk in power stations are limited to combustible liquids that lend themselves to control and extinguishment by water-type protective systems.

In order to ensure satisfactory results on such fires, the system design should take into account the physical nature of the expected fire, which will take one or more of three forms: a pressure jet or spray, a three-dimensional rundown of burning fuel over equipment and structures, or a spill or pool of fuel.

Fire experience with liquid fires in power stations confirms that a fire frequently displays multiple characteristics. A turbine-generator fire frequently originates as a spray fire at a bearing with burning oil running down to lower levels of the station where a spill or pool fire results. Similarly, a leak at an oil-fired boiler produces a spray fire with burning oil running down the boiler wall to a lower floor. A hydraulic oil leak on a fan drive likewise combines spray fire and spill fire characteristics.

A protective system is expected to control or extinguish a liquid fire, as well as provide exposure protection for the structure and equipment in the vicinity of the fire. The oil fire tests summarized in the following section indicate that complete extinguishment of pressure jet or spray fires may be difficult to achieve at any practical application density. The tests also show that spill or pool fires can be controlled, and equipment and structures in the general area protected, with area sprinkler protection operating at moderate densities [0.15 gpm/ft-0.20 gpm/ft^2 (6.11 L/min-m^2 - 8.15 L/min-m^2)]. Where the probable location of spray fires can be identified (e.g., exposed pipe runs without guard pipe or specific items of equipment), high velocity directional spray nozzles of open or fused type operating at applied densities of approximately 0.25 gpm/ft^2 (10.19 L/min-m^2) can radically limit the damage area resulting from a jet or spray fire.

The design specifics for water protective systems should be covered by the Fire Risk Evaluation based on the conditions existing in a particular plant.

C-1.2 Tests.

Limited fire testing has been conducted to develop design criteria for fire suppression systems for lubricating oil fires. The first series of tests were conducted by the Factory Mutual Research Corporation in 1957[1] under the sponsorship of the U.S. Atomic Energy Commission. These tests included large spill fires [up to 2100 ft^2 (195 m^2)], with ceiling heights similar to those found in turbine building lower elevations [33 ft (10 m)]. The tests showed that oil spill fires could be extinguished and structural damage held to a minimum with automatic sprinklers at ceiling level delivering a discharge density as low as 0.13 gpm/ft^2 (5.30 L/min-m^2). Also included in these tests was one oil spray fire test. This test showed that ceiling level sprinklers were unsuccessful at extinguishing the spray fire even with discharge densities up to 0.36 gpm/ft^2 (14.67 L/min-m^2). It further showed that damage caused by direct impingement of an oil spray fire on a structural column may not be prevented by ceiling sprinkler protection at a 0.36 density.

These pool fire tests involved a $^1/_4$ in. (6.35 mm) deep pool of oil but with normal building ventilation.

A later series of tests conducted in Finland in 1979[2] by a committee of insurance companies and utility companies showed similar results. These tests on oil spray and pool fires indicated the difficulty of extinguishing oil spray fires. Densities of up to 0.66 gpm/ft^2 (26.89 L/min-m^2) from automatic sprinklers 10 ft (3.05 m) overhead were unable to extinguish the spray fire. Water spray systems using high velocity and medium velocity spray nozzles were also tested on spray fires using densities up to 1.0 gpm/ft^2 (40.75 L/min-m^2). These tests showed the importance of nozzle placement in covering the entire oil spray to suppress a spray fire. Since the location and direction of an oil leak that could result in a spray fire is not readily predictable, the emphasis of water spray system design must be on area cooling to minimize fire damage rather than extinguishment of the spray fire. Tests showed that a density of 0.3 gpm/ft^2 (12.22 L/min-m^2) provided adequate cooling.

The Finnish tests also included pool fires in a collection pan of approximately 130 ft^2, 1 ft deep (12.08 m^2, 0.30 m). These tests showed that even distribution of 0.18 gpm/ft^2 (7.33 L/min-m^2) could extinguish an oil pool fire.

The difference in densities for oil pool fires between the two test series may be the result of test conditions. The Finnish test series involved a 12 in. (30.48 cm) deep pool of oil with ventilation rates of 75,000 cfm to enable filming of the test.

C-2 Fire-Resistant Fluid.

C-2.1 General.

In the United States, less flammable hydraulic fluids have been used in the control oil systems of larger turbines for a number of years. In the countries that formerly comprised the U.S.S.R.

these fluids are used for both the control and lubrication oil systems of steam turbines. Loss experience where this information is available (U.S.) has been good. Incidents involving less hazardous hydraulic fluids have resulted in relatively minor fires causing little damage. In one instance a utility indicated that a 1 in. (2.5 cm) diameter leak occurred in a control oil system with fluid sprayed onto a 1000°F (538°C) surface. A small fire resulted that was easily extinguished with a light water spray. Operators were able to isolate the line with no property damage and a one hour delay in startup. Plant personnel estimated that if mineral oil was involved under the same conditions a severe fire would have occurred with no possibility of the operators accessing the area to isolate the leak. This would have resulted in major fire damage and an extended outage.

C-2.2 Tests.

One of the listing organizations for less flammable fluids conducts the following two tests to qualify less flammable hydraulic fluids for listing. In both tests, the fluid is heated to 140°F (60°C) and discharged through an oil burner type, 80 degree hollow cone spray nozzle at 1000 psi (6.7 MPa). The tests are as follows:

(a) *Hot Surface Ignition Test:* The fluid is sprayed onto a steel channel heated to 1300°F (704°C). The spray is directed onto the heated surface for 60 seconds from a distance of 6 in. (15.2 cm). If ignition occurs the spray pattern is directed away from the hot surface to an open area. Local burning on the channel is acceptable. It is not acceptable if flame follows the spray pattern to the open area.

(b) *Flame Propagation Test:* A propane torch is used to ignite the spray 6 in. (15.2 cm) and at 18 in. (44.7 cm) from the nozzle. Ten tests are conducted at each location with the torch flame moved through the spray pattern. It is not acceptable if the spray burns longer than five seconds after the torch is removed from the spray pattern in any of the 20 tests.

C-3 Grouped Cable Fire Tests.

C-3.1 General.

The fire hazard presented by grouped cables depends on the number of trays in a given area, arrangement of trays (vertical vs. horizontal), type of cable used, arrangement of cable in the tray, and the type of tray (ladder vs. solid bottom). The tests indicated that water could penetrate densely packed ladder cable trays arranged six trays high, and although fire propagation could be limited in the horizontal direction, it would probably involve the entire array in the vertical direction. A 0.30 gpm/ft^2 (12.22 L/min-m^2) design density from ceiling sprinklers was effective. However, lower densities were not tried on full scale tests.

C-3.2 Tests.

Three fire test programs have been carried out using water to extinguish grouped cable fires. All tests involved polyethylene insulated, PVC jacketed cable in ladder type cable trays. The first series of tests was carried out by a group of insurance companies in Finland in 1975.[3] The tests involved protection of cables in a $6^1/_2$ ft × $6^1/_2$ ft × 65 ft (1.98 m × 1.98 m × 19.82 m) long enclosure similar to a cable tunnel. Six cable trays were located along each side of the tunnel.

Protection consisted of 135°F (57.2°C) rated sprinklers spaced 13 ft^2 (4 m) apart at ceiling level. A 0.40 gpm/ft^2 (16.30 L/min-m^2) density was used for the sprinkler system. The tests showed the ability of a sprinkler system to prevent horizontal fire spread in the group of six trays where the fire started and to protect cables on the opposite wall of the tunnel.

The second series of tests were carried out by the Central Electricity Generating Board of the United Kingdom in 1978.[4] The purpose was to compare the effectiveness of a deluge system activated by heat detection wire with a fusible link actuated automatic sprinkler system.

Cable trays were arranged six trays high and two trays wide (12 trays).

The water spray system was activated by a 160°F (71.1°C) rated heat detector wire. The wire was installed 9 in. (22.86 cm) above each cable tray and along the center of the bottom tray. Spray nozzles were positioned at 10-ft (3.05-m) intervals at ceiling level in the aisle between cable tray arrays. The automatic sprinkler system was located directly above the cable tray array with sprinkler heads spaced 10 ft (3.05 m) apart.

This test series showed that both protection systems could control a fire involving grouped cable. The water spray system responded faster with less fire damage to cable. The water spray system limited damage to cables in one or two trays. The sprinkler system limited damage to six to nine trays.

The third test program was conducted by the Factory Mutual Research Corporation[5] under the sponsorship of the Electric Power Research Institute.

One phase of the tests studied the ability of a ceiling sprinkler system to control a fire in a cable tray array. Cable trays were arranged six trays high and two trays wide with a number of vertical cable trays in the space between. The test was carried out in a room 40 ft × 40 ft × 20 ft high (12.20 m × 12.20 m × 6.10 m high). Protection consisted of 160°F (71.1°C) rated sprinklers on 10 ft × 10 ft (3.05 m × 3.05 m) spacing at ceiling level. A 0.30 gpm/ft^2 (12.22 L/min-m^2) density was used. Ionization detectors were provided at ceiling level.

Where sprinklers actuated, from one to three sprinklers opened to control the fire. Fire propagated the entire height of vertical trays, but could be contained within the 8 ft (2.44 m) length of most of the horizontal trays. Cable was damaged in most of the trays. Ionization detectors responded within 21 to 25 seconds.

C-4 Stack Liner Fire Tests.

C-4.1 General.

Tests were conducted on four fire-retardant fiberglass reinforced plastic liners by Factory Mutual Research Corporation.[6] The liners were 3 ft (0.91 m) in diameter and 30 ft (9.15 m) long. They were suspended vertically above a 10 ft^2 (0.93 m) pan containing 3 in. (7.62 cm) of heptane. The liners were exposed to this ignition source for 2$^1/_2$ minutes, at which time the pan was removed.

C-4.2 Tests.

Results were similar with all four materials tested. There was an initial moderate temperature rise due to the heat input from the heptane fire, a leveling off of temperature prior to involvement of the plastic, then a very rapid temperature increase caused by heat contribution from the burning liner; another leveling off during a period of active liner burning, then a decrease in temperature coincident with removal of the exposure fire. From a review of the test data, it appeared that once burning of the liner started, fire spread over the surface was almost instantaneous. Temperatures at different elevations in the liner interior reached 1000°F (537.8°C) almost simultaneously in each test.

REFERENCES:

1. “Fire Tests of Automatic Sprinkler Protection for Oil Spill Fires,” Factory Mutual Research Corp., September 9, 1957.

2. “Sprinkler and Water Spray Tests on Turbine Oil Fires,” Industrial Mutual Insurance Co., December, 1979.

3. “Sprinkler Tests in a Cable Duct (Tunnel) in Rautaruukki Oy’s Factory in Raahe,” Industrial Mutual Insurance Co., 1975.

4. “Report on the Performance of Fire Fighting Equipment Utilizing Water Spray When Initiated by Heat Detecting Cable,” Central Electricity Generating Board, February, 1978.

5. “Fire Tests in Ventilated Rooms Extinguishment of Fire in Grouped Cable Trays.” Electric Power Research Institute, EPRI NP-2660, December, 1982.

6. “Tests of Candidate Glass Fiber-Reinforced Stack Liner Materials,” Factory Mutual Research Corporation, July, 1975.

Appendix D Emergency Shutdown

This Appendix is not a part of the recommendations of this NFPA document but is included for informational purposes only.

The following describes fire experience that has occurred over the last several years where lubricating oil supply was shut down more rapidly than normal, either intentionally or accidentally. Lubricating oil was shut off at 0 rpm for fire No. 1, at 1000 rpm for fire No. 2, from 1000 rpm - 1400 rpm for fire No. 3, and in excess of 3000 rpm for fire No. 4.

No. 1. In August 1989 a 640 MW(e) five casing, double reheat machine with inlet steam pressure at 3675 psig (25,339 kPa) and 1000°F (537.8°C) was operating normally when a fire was discovered near the main lube oil tank. Unsuccessful attempts were made to manually fight the fire when control cable burned through and control and throttle valves started to close. At six minutes the ac lube oil pump started. The operator sent an assistant to vent hydrogen from the generator and purge with carbon dioxide. A valve was then manually operated to break condenser vacuum. This action resulted in reducing the coast-down time to 30 minutes from 45 minutes - 60 minutes. When the shaft stopped rotating, the operator took the unit off turning gear and shut down the ac and emergency dc oil pumps. The fire department and plant fire brigade quickly controlled the fire with one $2^1/_2$ in. (6.4 cm) and one $1^1/_2$ in. (3.8 cm) hose stream.

There was no damage to the bearings as a result of the shutdown. A runout check indicated that measured clearances were well within tolerance. Steel beams supporting the operating floor sagged from 2 in. (5 cm) to 3 in. (7.6 cm) over a 1500 ft^2 (138 m^2) area in front of the front standard. Cable, in trays near the fire area, was damaged. The action taken by the operator resulted in substantially reduced damage to the turbine and the building, and was credited with substantially reducing the length of time the turbine was out of service. The turbine was put back on turning gear about 26 days after the fire. The operating floor could be reinforced, and the unit operated until the next scheduled outage.

No. 2. In July 1987 a 35 MW(e) single flow, double automatic extraction, condensing machine with inlet steam pressure of 1250 psig (8618 kPa) and 900°F (482°C) was operating normally while millwrights attempted to clean the oil cooler tubes on one of the two oil coolers. During the cleaning process one of the tubes dropped out of the tube sheet and oil was ejected vertically at about 40 psi (275.8 kPa) through a $^5/_8$ in. (1.6 cm) opening in the tube sheet. The oil spray ignited off a steam stop valve overhead. Approximately 20 ceiling sprinklers and 16 spray nozzles directly below the operating floor opened. Oil mist and droplets passed up through a 6 in. (15.2 cm) wide opening between the operating floor and the wall and burned above the operating floor. Approximately 15 minutes into the fire, fearing building collapse, the ac driven lubricating oil pumps were shut off. The fire intensity decreased noticeably. Approximately 15 minutes later (30 minutes into the fire) the dc pump was shut down with the turbine turning at approximately 1000 rpm. The oil fire was quickly extinguished.

The main shaft bearings were wiped, and the thrust bearing destroyed. There were indications of minor rubbing at the high pressure end, and hangars for the main steam stop valve were cracked. There was little evidence of high temperatures in the basement area, due to the effect of the automatic sprinkler protection. However, there was a large amount of deformed structural steel above the operating floor, on the wall, and at roof level.

No. 3. In January 1989 a 12.5 MW(e) condensing, double automatic extraction turbine with inlet steam pressure of 475 psig (3275 kPa) and 750°F (400°C) was operating normally when maintenance personnel discovered a drip-sized leak at an elbow on the control oil piping. Control room personnel were notified, and, since they had difficulty reducing load, they tripped the unit by opening the breaker. A fire started in the vicinity of the hydraulic cylinder. There was no fixed protection provided, personnel attempted to fight the fire with hand extinguishers and hose streams without success. Two minutes after the fire started, with the machine turning at between 1100 rpm and 1400 rpm, the operator was ordered to stop the main and emergency oil pumps. Approximately 150 gal (568 L) of oil were lost before pumps were stopped. The fire department responded four minutes after the fire started and using one $2^1/_2$ in. (6.4 cm) and two $1^3/_4$ in. (4.4 cm) hose lines brought the fire under control 23 minutes after it started.

There was damage to turbine bearings, and the shaft ends were scored. In addition all control wiring under the turbine shroud was burned, and there was damage to gauges, indicators, and controls mounted in the turbine shroud. Structural steel was warped at the roof of the building. Repairs to the turbogenerator were estimated at 2 to 3 weeks.

No. 4. In February 1988 two 660 MW(e) units were operating at 550 and 530 MW(e), respectively. The units were end to end. Power and control cable for the lube oil pump motors for both machines were located above a control valve servomotor enclosure for one of the units. Piping to the enclosure was guarded and contained control oil at 250 psig (1724 kPa). A leak occurred in the control oil piping within the guard pipe. The turbine tripped automatically. Oil flooded the guard pipe and backed up into the servomotor enclosure igniting in the vicinity of the main steam stop valves. The fire damaged power and control cable for both machines shutting down ac and dc oil pumps for both units. Both machines were rotating in excess of 3000 rpm at the time lube oil was lost.

Extensive repairs were needed to mill bearing surfaces and to straighten and balance the shafts on both units. One machine was out of service for approximately three months, the other for five months.

Appendix E Referenced Publications

E-1

The following documents or portions thereof are referenced within this recommended practice for informational purposes only and thus are not considered part of the recommendations of this document. The edition indicated for each reference is the current edition as of the date of the NFPA issuance of this document.

E-1.1 NFPA Publication.

National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.

NFPA 1561, *Standard on Fire Department Incident Management System,* 1995 edition.

NFPA 851

1996 Edition

Recommended Practice for Fire Protection for Hydroelectric Generating Plants

1996 Edition

This edition of NFPA 851, *Recommended Practice for Fire Protection for Hydroelectric Generating Plants*, was prepared by the Technical Committee on Electric Generating Plants and acted on by the National Fire Protection Association, Inc., at its Fall Meeting held November 13-15, 1995, in Chicago, IL. It was issued by the Standards Council on January 12, 1996, with an effective date of February 2, 1996, and supersedes all previous editions.

Changes other than editorial are indicated by a vertical rule in the margin of the pages on which they appear. These lines are included as an aid to the user in identifying changes from the previous edition.

This edition of NFPA 851 was approved as an American National Standard on February 2, 1996.

Origin and Development of NFPA 851

The Committee on Non-Nuclear Power Generating Plants was organized in 1979 to have primary responsibility for documents on fire protection for non-nuclear electric generating plants. The Hydroelectric Subcommittee was formed in 1982 to write this document. The first edition of NFPA 851 was issued in 1987 and revised in 1992. The 1996 edition contains minor changes to clarify the life safety recommendations and generator windings protection.

Technical Committee on Electric Generating Plants

Leonard R. Hathaway, *Chair*
M&M Protection Consultants, IL

Kenneth W. Dungan, *Vice Chair*
HSB Professional Loss Control Inc., TN

Lee T. Warnick, *Secretary*
Virginia Power Co., VA

Michael L. Alford, Stone Container Corp., IL

Thomas L. Allen, U.S. Fidelity & Guaranty Co., MD
Rep. American Insurance Services Group, Inc.

Donald C. Birchler, FP&C Consultants Inc., MO

Bernhard G. Bischoff, Figgie Fire Protection Systems, IL
Rep. Fire Suppression Systems Assn.

Harold D. Brandes, Jr., Duke Power Co., NC

Stanley J. Chingo, VECTRA Technologies, Inc., IL

Thomas C. Clayton, Black & Veatch, MO

Harry M. Corson, Cerberus Pyrotronics, NJ
Rep. Nat'l Electrical Mfrs. Assn.

Phillip A. Davis, Kemper Nat'l Insurance Companies, PA

Donald A. Diehl, Alison Control Inc., NJ

Paul H. Dobson, Factory Mutual Research Corp., MA

Don Drewry, Hartford Steam Boiler Inspection & Insurance Co., NJ

James F. Foley, New York Power Authority, NY

Ismail M. Gosla, Fluor Daniel, CA

Dwight S. Hull, Tennessee Valley Authority, TN

Everett C. Hume, Industrial Risk Insurers, CT
Rep. Industrial Risk Insurers

John W. Koester, Johnson & Higgins, MD

Amjad M. Mian, Manitoba Hydro, Canada

James G. Pittman, Seminole Electric Cooperative Inc., FL

Gregory W. Powell, Baltimore Gas & Electric Co., MD

John G. Puder, F. E. Moran Inc., IL

Joseph F. Scarduzio, Sr., Ratheon Engr & Constructors, PA

Omer Semen, Ratheon Engr & Constructors, NY

William D. Snell, TU Services Inc., TX

Steven F. Vieira, Grinnell Corp., RI
Rep. Nat'l Fire Sprinkler Assn.

Lynn C. Wall, Sedgwick James of Georgia, GA

R. L. Welch, Cincinnati Gas & Electric Co., OH
Rep. Electric Light Power Group/Edison Electric Inst.

Alternates

Patrick T. Borns, McDaniel Fire Systems Inc., IN
(Alt. to B. G. Bischoff)

John K. Bouchard, Sedgwick James of New England, MA
(Alt. to L. C. Wall)

Fernando A. Caycedo, Ratheon Engr & Constructors, GA
(Alt. to O. Semen)

James M. Connolly, M&M Protection Consultants, IL

(Alt. to L. R. Hathaway)

Robert E. Dundas, Factory Mutual Research Corp., MA
(Alt. to P. H. Dobson)

Rickey L. Johnson, Cigna Loss Control Services, CT
(Alt. to T. L. Allen)

Robert A. Kuchinski, Hartford Steam Boiler Inspection & Insurance Co., CT
(Alt. to D. Drewry)

Yuvonne L. Moore, Stone Container Corp., IL
(Alt. to M. L. Alford)

James F. Mulvoy, Alison Control Inc., IL
(Alt. to D. A. Diehl)

Charles R. Prasso, Industrial Risk Insurers, CT
(Alt. to E. C. Hume)

Samuel L. Rogers, Kemper Nat'l Insurance Companies, OH
(Alt. to P. A. Davis)

Steven A. Sheldon, Johnson & Higgins, AZ
(Alt. to J. W. Koester)

Daniel J. Sheridan, Black & Veatch, MO
(Alt. to T. C. Clayton)

Gary D. Taylor, Duke Power Co., NC
(Alt. to H. D. Brandes)

Richard Wickman, Baltimore Gas & Electric Co., MD
(Alt. to G. W. Powell)

Richard P. Bielen, NFPA Staff Liaison

This list represents the membership at the time the Committee was balloted on the text of this edition. Since that time, changes in the membership may have occurred.

NOTE: Membership on a Committee shall not in and of itself constitute an endorsement of the Association or any document developed by the Committee on which the member serves.

Committee Scope: This Committee shall have primary responsibility for documents on fire protection for electric generating plants and high voltage direct current (HVDC) converterstations, except for electric generating plants using nuclear fuel.

NFPA 851

Recommended Practice for Fire Protection for Hydroelectric Generating Plants

1996 Edition

NOTICE: An asterisk (*) following the number or letter designating a paragraph indicates explanatory material on that paragraph in Appendix A.
Information on referenced publications can be found in Chapter 7.

Chapter 1 Introduction

1-1 Scope.

This document provides recommendations (not requirements) for fire prevention and fire protection for hydroelectric generating plants. The term “hydroelectric generating plant” also may be referred to as “station,” “project,” “unit(s),” “facility,” or “site.”

1-2 Purpose.

1-2.1

This document provides guidance for those charged with the design, construction, and operation of hydroelectric generating plants.

1-2.2

This document provides fire prevention and fire protection recommendations primarily to safeguard physical property and continuity of power production, but its application can also enhance safety of site personnel. This document is not intended to restrict new technologies or alternate arrangements.

1-3 Application.

1-3.1

This document is intended for use by persons knowledgeable in the application of fire protection to hydroelectric generating plants.

1-3.2

The recommendations contained in this document are intended for new installations only, as the application to existing installations might not be practicable.

1-3.3

It should be recognized that rigid uniformity of generating station design and operating procedures does not exist and that each facility will have its own special conditions that impact on the nature of the installation. Many of the specific recommendations herein may require modification after due consideration of all local factors involved. Individual generating units, particularly those of less than 25 MW, should be given a cost-benefit analysis to determine the extent to which fire protection is justified.

1-4 Definitions.

Approved.* Acceptable to the authority having jurisdiction.

Authority Having Jurisdiction.* The organization, office, or individual responsible for approving equipment, an installation, or a procedure.

Combustible. Any material that does not comply with the definition of either noncombustible or limited combustible.

Combustible Liquid. A liquid having a flash point at or above 100°F (37.8°C). (*See NFPA 30, Flammable and Combustible Liquids Code.*)

Fire Barrier. A fire barrier is a continuous membrane, either vertical or horizontal, such as a wall or floor assembly, that is designed and constructed with a specified fire resistance rating to limit the spread of fire and that will also restrict the movement of smoke. Such barriers may have protected openings.

Fire Loading. The amount of combustibles present in a given area, expressed in Btu/ft^2 (kJ/m^2).

Fire Point. The lowest temperature at which a liquid in an open container will give off sufficient vapors to burn once ignited. It is generally slightly above the flash point.

Fire Prevention. Measures directed towards avoiding the inception of fire.

Fire Protection. Methods of providing for fire control or fire extinguishment.

Fire Protection Rating. The time, in minutes or hours, that materials and assemblies used as opening protection have withstood a fire exposure as established in accordance with test procedures of NFPA 252, *Standard Methods of Fire Tests of Door Assemblies*, and NFPA 257, *Standard for Fire Tests of Window Assemblies*, as applicable.

Fire Rated Penetration Seal. An opening in a fire barrier for the passage of pipe, cable, duct, etc., that has been sealed so as to maintain a barrier rating.

Fire Resistance Rating. The time, in minutes or hours, that materials or assemblies have withstood a fire exposure as established in accordance with the test procedures of NFPA 251, *Standard Methods of Tests of Fire Endurance of Building Construction and Materials*.

Flammable Liquid. Any liquid having a flash point below 100°F (37.8°C) and having a vapor pressure not exceeding 40 psia (276 kPa) absolute pressure at 100°F (37.8°C). (*See NFPA 30, Flammable and Combustible Liquids Code.*)

High Fire Point Liquid. A combustible dielectric liquid listed as having a fire point of not less than 572°F (300°C).

Interior Finish. The exposed interior surfaces of buildings including, but not limited to, fixed or movable walls and partitions, columns, and ceilings. Interior finish materials are grouped in the following classes:

Class A Interior Finish. Materials having flame spread 0-25, smoke developed 0—450 when tested in accordance with NFPA 255, *Standard Method of Test of Surface Burning Characteristics of Building Materials*. Includes any material classified at 25 or less on the flame spread test scale and 450 or less on the smoke test scale when any element thereof, when tested, does not continue to propagate fire.

Class B Interior Finish. Materials having flame spread 26-75, smoke developed 0—450 when tested in accordance with NFPA 255, *Standard Method of Test of Surface Burning Characteristics of Building Materials*. Includes any material classified at more than 25, but not more than 75, on the flame spread test scale and 450 or less on the smoke test scale.

Labeled. Equipment or materials to which has been attached a label, symbol, or other identifying mark of an organization that is acceptable to the authority having jurisdiction and concerned with product evaluation that maintains periodic inspection of production of labeled equipment or materials and by whose labeling the manufacturer indicates compliance with appropriate standards or performance in a specified manner.

Less Flammable Liquid. A combustible dielectric liquid listed as having a fire point of not less than 572°F (300°C).

Limited Combustible. As applied to a building construction material, a material, not complying with the definition of noncombustible material, that in the form in which it is used has a potential heat value not exceeding 3500 Btu/lb (8.14×10^6 J/kg) (see NFPA 259, *Standard Test Method for Potential Heat of Building Materials*), and complies with one of the following paragraphs (a) or (b).

(a) Materials having a structural base of noncombustible material with a surfacing not exceeding a thickness of $^1/_8$ in. (3.175 mm) that has a flame spread rating not greater than 50.

(b) Materials, in the form and thickness used, other than as described in (a), having neither a flame spread rating greater than 25 nor evidence of continued progressive combustion, and of such composition that the surfaces that would be exposed by cutting through the material on any plane would have neither a flame spread rating greater than 25 nor evidence of continued progressive combustion as tested in accordance with NFPA 255, *Standard Method of Test of Surface Burning Characteristics of Building Materials*.

Materials subject to increase in combustibility or flame spread rating beyond the limits herein established through the effects of age, moisture, or other atmospheric condition are considered combustible.

Listed.* Equipment or materials included in a list published by an organization acceptable to the authority having jurisdiction and concerned with product evaluation that maintains periodic inspection of production of listed equipment or materials and whose listing states either that the equipment or material meets appropriate standards or has been tested and found suitable for use in a specified manner.

Noncombustible. A material that, in the form in which it is used and under the conditions anticipated, will not aid combustion or add appreciable heat to an ambient fire. Materials when tested in accordance with ASTM E136, *Standard Test Method for Behavior of Materials in a Vertical Tube Furnace at 750°C*, and conforming to the criteria contained in Section 7 of the referenced standard shall be considered noncombustible.

Nonflammable Fluid. A nonflammable dielectric fluid that does not have a flash point and is not flammable in air.

Should. Indicates a recommendation or that which is advised but not required.

1-5 Units.

Metric units in this document are in accordance with the International System of Units, which is officially abbreviated SI in all languages. For a full explanation, see ASTM E380/ANSI Z210.1, *Metric Practice Guide*.

Chapter 2 Administrative Controls

2-1 General.

2-1.1

This chapter provides recommended criteria for the development of administrative procedures and controls necessary for the execution of the fire prevention and fire protection activities and practices for hydroelectric generating plants.

2-1.2

The administrative controls recommended in this chapter should be reviewed and updated periodically.

2-1.3

The intent of this chapter can be met by incorporating the features of this chapter in the plant's operating procedures or otherwise as determined by plant management.

2-2 Management Policy and Direction.

2-2.1

Corporate management should establish a policy and institute a program to promote the conservation of property and continuity of operations as well as protection of safety to life by adequate fire prevention and fire protection measures at each facility.

2-2.2

Proper preventative maintenance of operating equipment as well as adequate operator training are important aspects of a viable fire prevention program.

2-3 Fire Risk Evaluation.

A Fire Risk Evaluation should be initiated early in the design process to ensure that the fire prevention and fire protection recommendations as described in this document have been evaluated in view of the plant's specific considerations regarding design, layout, and anticipated operating requirements. The evaluation should result in a list of recommendations based on acceptable means for separation or control of common and special hazards, the control or elimination of ignition sources, and the suppression of fires.

2-4 Fire Prevention Program.

A written plant fire prevention program should be established and, as a minimum, should include the following:

(a) Fire safety information for all employees and contractors. This information should include, as a minimum, familiarization with fire prevention procedures, plant emergency alarms and procedures, and how to report a fire.

(b) Documented plant inspections including provisions for remedial actions to correct conditions that increase fire hazards.

(c) A description of the general housekeeping practices and the control of transient combustibles.

(d) Control of flammable and combustible liquids and gases in accordance with appropriate NFPA standards.

(e) Control of ignition sources to include smoking, grinding, welding, and cutting. (*See NFPA 51B, Standard for Fire Prevention in Use of Cutting and Welding Processes*.)

(f) Fire prevention surveillance. (*See NFPA 601, Standard for Security Services in Fire Loss Prevention.*)

(g) Fire report, including an investigation and a statement on the corrective action to be taken. (*See Appendix B.*)

2-5 Testing, Inspection, and Maintenance.

2-5.1

Upon installation, all fire protection systems should be preoperationally inspected and tested in accordance with applicable NFPA standards. Where appropriate standards do not exist, inspection and test procedures outlined in the purchase and design specifications should be followed.

2-5.2

All fire protection systems and equipment should be periodically inspected, tested, and maintained in accordance with applicable *National Fire Codes®*. (*See Table 2-5.2 for guidance.*)

Table 2-5.2 Reference Guide for Fire Equipment Inspection, Testing, and Maintenance

Item	NFPA No.
Supervisory and Fire Alarm Circuits	72
Fire Detectors	72
Manual Fire Alarms	72
Sprinkler Water Flow Alarms	13/72
Sprinkler and Water Spray Systems	15/13
Foam Systems	11A/11C/16
Halogenated Agent, Chemical, & CO_2 Systems	12/12A/17
Fire Pumps & Booster Pumps	20
Water Tanks & Alarms	13/22/72
P.I.V.s and O.S. & Y. Valves	13/72
Fire Hydrants and Associated Valves	13/24
Fire Hose and Standpipes	14/1962

Portable Fire Extinguishers & Hose Nozzles	10/1962
Fire Brigade Equipment	1971/1972/1973/1974
Fire Doors	80
Smoke Vents	204M
Emergency Lighting	70
Radio Communication Equipment	1221

NOTE: Inspection intervals for unattended plants may be permitted to be extended to normal plant inspections.

2-5.3

Testing, inspection, and maintenance should be documented with written procedures, results, and follow-up actions recorded.

2-6 Impairments.

2-6.1

A written procedure should be established to address impairments to fire protection systems, and as a minimum this procedure should include the following:

(a) Identification and tracking of impaired equipment.

(b) Identification of personnel to be notified (e.g., plant fire brigade chief, public fire department, etc.).

(c) Determination of needed fire protection and fire prevention measures.

2-6.2

Impairments to fire protection systems should be as short in duration as practical. If the impairment is planned, all necessary parts and personnel should be assembled prior to removing the protection system(s) from service. When an impairment is not planned, or when a system has discharged, the repair work or system restoration should be expedited.

2-6.3

Proper reinstallation after maintenance or repair should be performed to ensure proper systems operation. Once repairs are complete, tests that will ensure proper operation and restoration of full fire protection equipment capabilities should be made. Following restoration to service, the parties previously notified of the impairment should be advised. The latest revision of the design documents reflecting as-built conditions should be available to ensure that the system is properly reinstalled (e.g., drawings showing angles of nozzles).

2-7 Fire Emergency Plan.

A written fire emergency plan should be developed, and, as a minimum, this plan should include the following:

(a) Response to fire alarms and fire systems supervisory alarms.

(b) Notification of personnel identified in the plan.

(c) Evacuation of personnel not directly involved in fire-fighting activities from the fire area.

(d) Coordination with security forces or other designated personnel to admit public fire department and control traffic and personnel.

(e) Fire extinguishment activities.

(f) Periodic drills to verify viability of the plan.

(g) Control room operator(s) activities during fire emergencies. Approved breathing apparatus should be readily available in the control room area.

2-8 Fire Brigade.

2-8.1

The size of the plant and its staff, the complexity of fire-fighting problems, and the availability and response time of a public fire department should determine the requirements for a fire brigade.

2-8.2*

If a fire brigade is provided, its organization and training, including special fire-fighting conditions unique to hydroelectric plants, should be outlined in written procedures.

2-8.3

Cable tray fires, unique to hydroelectric generating plants, should be handled like any fire involving energized electrical equipment. It may not be practical or desirable to deenergize the cables involved in the fire. Water is the most effective extinguishing agent for cable insulation fires but should be applied with an electrically safe nozzle. Some cables [polyvinyl chloride (PVC), Neoprene, or Hypalon] can produce dense smoke in a very short time. In addition, PVC liberates hydrogen chloride (HCl) gas. Self-contained breathing apparatus should be used by personnel attempting to extinguish cable tray fires.

Chapter 3 General Plant Design

3-1 Plant Arrangement.

3-1.1 Fire Area Determination.

3-1.1.1 The hydroelectric generating plant should be subdivided into separate fire areas as determined by the Fire Risk Evaluation for the purposes of limiting the spread of fire, protecting personnel, and limiting the resultant consequential damage to the plant. Fire areas should be separated from each other by approved fire barriers, spatial separation, or other approved means.

3-1.1.2 Determination of fire area boundaries should be based on consideration of the following: types, quantity, density, and locations of combustible material; location and configuration of plant equipment; consequences of losing plant equipment; location of fire detection and suppression systems; and personnel safety/exit requirements. It is recommended that most fire barriers separating fire areas be of two hours fire resistance rating. If a fire area is defined as a detached structure, it should be separated from other structures by an appropriate distance. (*See NFPA 80A, Recommended Practice for Protection of Buildings from Exterior Fire Exposures.*) Unless consideration of the above factors indicates otherwise, it is recommended that fire area boundaries be provided as follows:

(a) To separate cable spreading room(s) and cable tunnel(s) from adjacent areas.

(b) To separate the control room, computer room, or combined control/computer room from adjacent areas. Where the control room and computer room are separated by a common wall, the wall need not have a fire resistance rating.

(c) To separate rooms with major concentrations of electrical equipment, such as switchgear room and relay room, from adjacent areas.

(d) To separate battery rooms from adjacent areas.

(e) To separate maintenance shop(s) from adjacent areas.

(f) To separate main fire pump(s) from reserve fire pump(s), where these pumps provide the only source of water for fire protection.

(g) To separate fire pumps from adjacent areas.

(h) To separate warehouses and combustible storage areas from adjacent areas.

(i) To separate emergency generators from each other and from adjacent areas.

(j) To separate oil storage and purification rooms from adjacent areas.

(k) To separate fan rooms and plenum chambers from adjacent areas (fire dampers may not be advisable in emergency ventilation ducts — see Section 3-4).

(l) To separate office areas from adjacent areas.

(m) To separate telecommunication rooms from adjacent areas.

(n) To separate the intake hoist housing from generator floor area and from adjacent areas.

(o) To separate the tailrace service gallery from turbine/generator floors and governor hydraulic equipment.

3-1.2 Outdoor Oil-Insulated Transformers.

3-1.2.1 Outdoor oil-insulated transformers should be separated from adjacent structures and from each other by firewalls, spatial separation, or other approved means for the purpose of limiting the damage and potential spread of fire from a transformer failure.

3-1.2.2 Determination of the type of physical separation should be based on consideration of the following:

(a) type and quantity of oil in the transformer,

(b) size of a postulated oil spill (surface area and depth),

(c) type of construction of adjacent structures,

(d) power rating of the transformer,

(e) fire suppression systems provided, and

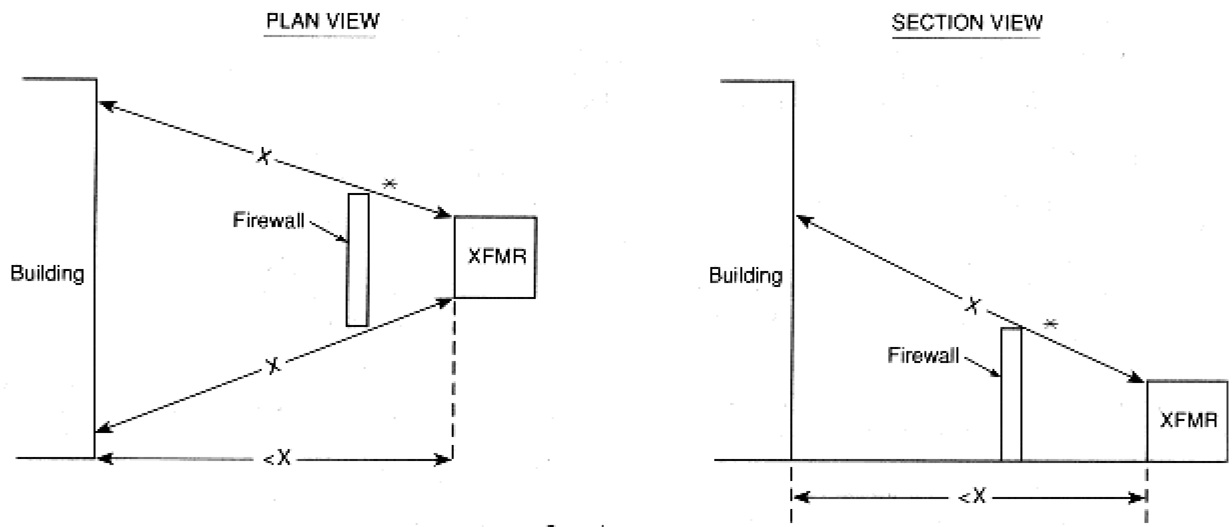
(f) type of electrical protective relaying provided.

3-1.2.3 Unless consideration of the factors in 3-1.2.2 indicates otherwise, it is recommended that any oil-insulated transformer containing 500 gal (1893 L) or more of oil be separated from adjacent noncombustible or limited combustible structures by a 2-hr rated firewall or by spatial separation in accordance with Table 3-1.2.3. Where a firewall is provided between structures and a transformer, it should extend vertically and horizontally as indicated in Figure 3-1.2.3.

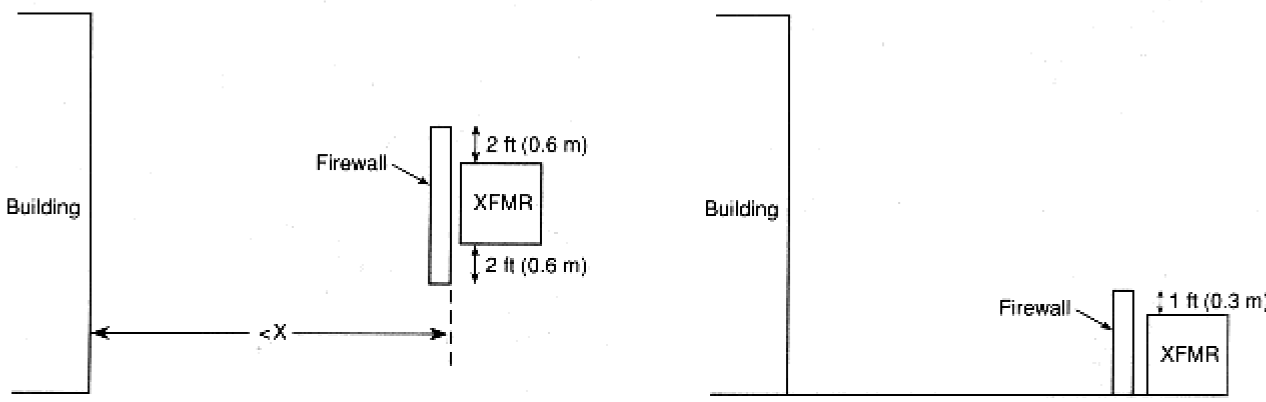
NOTE: As a minimum, the firewall should extend at least 1 ft (0.31 m) above the top of the transformer casing and oil conservator tank and at least 2 ft (0.61 m) beyond the width of the transformer and cooling radiators.

Table 3-1.2.3 Outdoor Oil-Insulated Transformer Separation Criteria

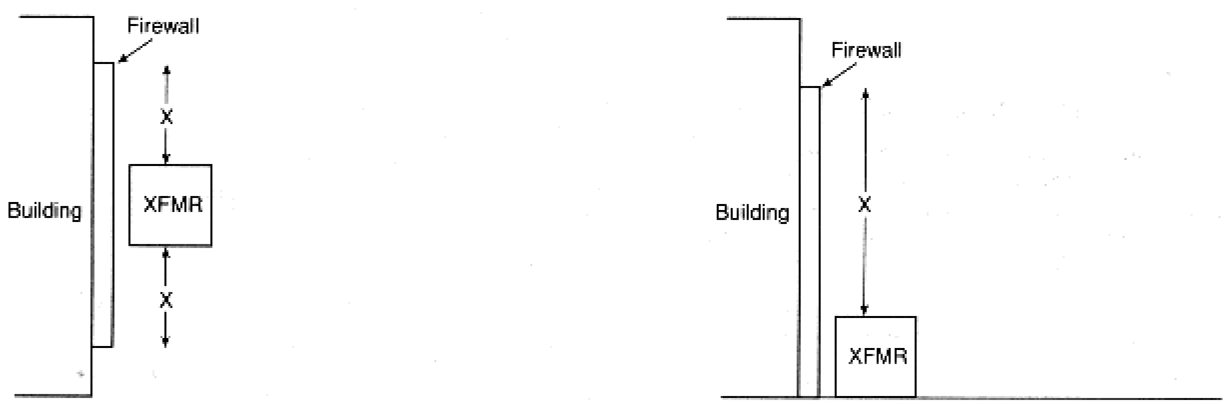
Transformer Oil Capacity	Minimum (Line-of-Sight) Separation without Firewall
Less than 500 gal (1893 L)	See 3-1.2.2
500 gal to 5000 gal (1893-18,925 L)	25 ft (7.6 m)
over 5000 gal (18,925 L)	50 ft (15 m)



Generic case



Example 1



Example 2

Figure 3-1.2.3 Illustration of oil-insulated transformer separation recommendations.

3-1.2.4 Unless consideration of the factors in 3-1.2.2 indicates otherwise, it is recommended that adjacent oil-insulated transformers containing 500 gal (1893 L) or more of oil be separated from each other by a 2-hr rated firewall or by spatial separation in accordance with Table 3-1.2.3. Where a firewall is provided between transformers, it should extend at least 1 ft (0.31 m) above the top of the transformer casing and oil conservator tank and at least 2 ft (0.61 m) beyond the width of the transformer and cooling radiators.

3-1.2.5 Where a firewall is provided, it should be designed to withstand the effects of exploding transformer bushings or lightning arrestors.

NOTE: A higher noncombustible shield may be permitted to be provided to protect against the effects of an exploding transformer bushing.

3-1.2.6 Where a firewall is not provided, the edge of the postulated oil spill (i.e., containment basin, if provided) should be separated by a minimum of 5 ft (1.5 m) from the exposed structure to prevent direct flame impingement on the structure.

3-1.2.7 Outdoor transformers insulated with a less flammable liquid should be separated from each other and from adjacent structures that are critical to power generation by firewalls or spatial separation based on consideration of the factors in 3-1.2.2, 3-1.2.5, and 3-1.2.6.

3-1.3 Indoor Transformers.

3-1.3.1 Dry-type transformers are preferred for indoor installations.

3-1.3.2 Oil-insulated transformers of greater than 100 gal (379 L) oil capacity installed indoors should be separated from adjacent areas by fire barriers of 3-hr fire resistance rating.

NOTE: Where multiple transformers of less than 100 gal (379 L) capacity each are located within close proximity, additional fire protection could be required based on the Fire Risk Evaluation.

3-1.3.3 Transformers insulated with less flammable liquids, having a rating above 35 KV and installed indoors, should be separated from adjacent areas by fire barriers of 3-hr fire resistance rating.

3-1.3.4 Where transformers are protected by an automatic fire suppression system, the fire barrier fire resistance rating may be permitted to be reduced to 1 hr.

3-1.4 Circuit Breakers.

3-1.4.1 The preferred location for oil circuit breakers is outdoors. Consideration should be given to dry or gas-cooled circuit breakers for indoor applications.

3-1.4.2 Oil-cooled circuit breakers should be separated from adjacent areas by fire barriers having a 3-hr fire resistance rating.

3-1.5 Openings in Fire Barriers.

3-1.5.1 All openings in fire barriers should be provided with fire door assemblies, fire dampers, penetration seals (fire stops), or other approved means having a fire protection rating consistent with the designated fire resistance rating of the barrier. Windows in fire barriers (e.g., control rooms or computer rooms) should be provided with a fire shutter or automatic water curtain. Penetration seals provided for electrical and piping openings should be listed or should meet the requirements for an “F” rating when tested in accordance with ASTM E814, *Fire Tests of*

Through-Penetration Fire Stops. Other test methods for qualifications of penetration seals, such as IEEE 634, *Testing Fire Rated Penetration Seals*, may be permitted to be considered for this application.

NOTE: Listed penetration seals for large diameter piping might not be commercially available. In such instances the design should be similar to listed configurations.

3-1.5.2 Fire door assemblies, fire dampers, and fire shutters used in 2-hr rated fire barriers should be rated not less than $1^1/_2$ hr. (*See NFPA 80, Standard for Fire Doors and Fire Windows.*)

3-2 Life Safety.

3-2.1

For life safety for hydroelectric generating plants, see NFPA *101*®, *Life Safety Code*®.

3-2.2

Structures should be classified as follows, as defined in NFPA *101*, *Life Safety Code*:

(a) General areas should be considered as special purpose industrial occupancies.

NOTE 1: Hydroelectric powerhouse structures protected in accordance with this document meet the intent of NFPA *101*, *Life Safety Code*, for additional travel distances for fully sprinklered facilities.

NOTE 2: NFPA *101* allows additional means of egress components for special purpose industrial occupancies. These areas may be permitted to be provided with fixed industrial stairs, fixed ladders (see ANSI A1264.1, *Safety Requirements for Workplace Floor and Well Openings, Stairs, and Railing Systems*, and ANSI A14.3, *Standard for Safety Requirements for Fixed Ladders*), or alternating tread devices (see NFPA *101*). Examples of these spaces include catwalks, floor areas, or elevated platforms that are provided for maintenance and inspection of in-place equipment.

NOTE 3: NFPA *101* allows spaces not subject to human occupancy because of the presence of machinery or equipment to be excluded from egress capacity requirements. Examples of these spaces include:

(1) Turbine scroll cases;

(2) Generators;

(3) Access tunnels for dam inspections;

(4) Entry into draft tubes; or

(5) Penstocks.

(b) Temporary occupancies and means of egress inside the structures and piers of large “bulb” units should be evaluated based on occupancies in special structures.

(c) Open structures and underground structures (e.g., tunnels) should be considered as occupancies in special structures.

(d) General office structures should be considered as business occupancies.

(e) Warehouses should be considered as storage occupancies.

3-3 Building Construction Materials.

3-3.1

Construction materials being considered for hydroelectric generating plants should be selected based on the Fire Risk Evaluation using the following standards:

(a) NFPA 220, *Standard on Types of Building Construction;*

(b) NFPA 251, *Standard Methods of Tests of Fire Endurance of Building Construction and Materials;*

(c) NFPA 253, *Standard Method of Test for Critical Radiant Flux of Floor Covering Systems Using a Radiant Heat Energy Source;*

(d) NFPA 255, *Standard Method of Test of Surface Burning Characteristics of Building Materials;*

(e) NFPA 259, *Standard Test Method for Potential Heat of Building Materials.*

3-3.2

Building components for all powerhouse and subsurface structures should be of noncombustible or limited combustible materials, except as noted in 3-3.3.

3-3.3

Roof coverings should be Class A in accordance with NFPA 256, *Standard Methods of Fire Tests of Roof Coverings*. Metal roof deck construction, where used, should be Class I listed or approved.

3-3.4 Interior Finish.

3-3.4.1 Cellular or foam plastic materials should not be used in interior finish in buildings critical to the generation processes or in subsurface structures.

3-3.4.2 Interior finish in buildings critical to power generation should be Class A.

3-3.4.3 Interior finish in buildings not critical to the generation processes should be Class A or Class B.

3-4 Smoke and Heat Venting, Heating, Ventilating, and Air Conditioning.

3-4.1 Smoke and Heat Venting.

3-4.1.1 Smoke and heat vents are not substitutes for normal ventilation systems unless designed for dual usage, and should not be used to assist such systems for comfort ventilation. Smoke and heat vents should not be left open where they can sustain damage from high wind conditions. They should be included in surveillance programs to ensure availability in emergency situations.

3-4.1.2 Heat vents should be provided for areas identified by the Fire Risk Evaluation. Where heat vents are provided, heat generated under fire conditions should be vented from its place of origin directly to the outdoors.

3-4.1.3 Smoke venting should be provided for areas identified by the Fire Risk Evaluation. Where smoke venting is provided, smoke should be vented from its place of origin in a manner that does not interfere with the operation of the plant.

3-4.1.3.1 Separate smoke ventilation systems are preferred; however, smoke venting can be integrated into normal ventilation systems using automatic or manually positioned dampers and motor speed control. (*See NFPA 90A, Standard for the Installation of Air Conditioning and Ventilating Systems, and NFPA 204M, Guide for Smoke and Heat Venting.*) Smoke venting also may be permitted to be accomplished through the use of portable smoke ejectors.

3-4.1.3.2 Consideration should be given to smoke venting for the following areas: control room, cable spreading room(s), and switchgear room.

3-4.1.3.3 In the areas with gaseous fire extinguishing systems, the smoke ventilation system should be properly interlocked to ensure the effective operation of the gaseous fire extinguishing systems.

3-4.1.3.4 Smoke removal system dampers, where installed, are normally operable only from an area immediately outside of, or immediately within, the fire area served since it is desired to have entry into, and inspection of, the fire area by fire-fighting personnel prior to restoring mechanical ventilation to the fire area. Smoke removal system dampers may be permitted to be operable from the control room if provisions are made to prevent premature operation. This can be accomplished using thermal interlocks or administrative controls.

3-4.1.4 The fan power supply wiring and controls for smoke exhaust should be located external to the fire area served by the fan or be installed in accordance with the Fire Risk Evaluation.

3-4.1.5 Ventilation exhaust systems, particularly those for subsurface portions of underground facilities, should have fans able to continuously exhaust smoke and chemical fumes that can result from fires or from extinguishing of fires. The design and selection of the fans and other elements of the system should take into account additional ventilation needs for removing smoke and high temperature gases. Therefore the fan and its associated components, along with any ductwork, should be capable of handling high temperatures without deforming. The specific weight and volume of the heated air during a fire and the climatic conditions should also be considered. Total fan capacity should be provided so that ventilation requirements can be met with the largest fan out of service.

NOTE: When fire heats air and introduces products of combustion into the air in tunnels and in underground hydroelectric plants, the ventilation conditions that existed while the air was cold are altered. Frictional resistance to flow of heated air containing products of combustion is much greater than frictional resistance to flow of cold air that does not contain products of combustion. In the event of mild heating, increased resistance to flow would decrease the rate of ventilation. Then, after the fire is contained and the air is cooled, the air and smoke could be evacuated. Therefore, considerations for the health and safety of people underground should cause the designers to increase the rate of evacuating hot air containing smoke. As the fire underground increases the temperature of the air, ventilation flow can be reversed. The cooler ventilating air may flow in one direction occupying much of the lower spaces of tunnels while plumes of heated air flow rapidly outward from the area of the fire beneath the tunnel ceiling in the opposite direction from, and above, the mass of cooler air. The designer should then consider the stratification of air flow, the numerous nodes or junctures between tunnels and shafts, the likely frictional resistances with and without fire, and the placement and capacities of the fans and fire stops. Some useful information is available in the proceedings of Session XI, *Fires*, of the 2nd International Mine Ventilation Congress. The designer is advised to be thoroughly familiar with Chapter 41, Fire and Smoke Control, in the *ASHRAE Handbook*.

3-4.2 Normal Heating, Ventilating, and Air Conditioning Systems.

3-4.2.1 For normal heating, ventilating, and air conditioning systems, see NFPA 90A, *Standard for the Installation of Air Conditioning and Ventilating Systems*, or NFPA 90B, *Standard for the Installation of Warm Air Heating and Air Conditioning Systems*, as appropriate.

3-4.2.2 Air conditioning for the control room should provide a pressurized environment to preclude the entry of smoke in the event of a fire outside the control room.

3-4.2.3 Plastic ducts, including listed fire-retardant types, should not be used for ventilating systems. Listed plastic fire-retardant ducts with appropriate fire protection may be permitted to be used in areas with corrosive atmospheres.

3-4.2.4 Fire dampers (doors) compatible with the rating of the barrier should be provided at the duct penetrations to the fire area (*see Section 3-1*) unless the duct is protected throughout its length by a fire barrier equal to the rating required of fire barrier(s) penetrated.

3-4.2.5 Smoke dampers, where installed, should be installed in accordance with NFPA 90A, *Standard for the Installation of Air Conditioning and Ventilating Systems*.

3-4.2.6 The fresh air supply intakes to all areas should be located remotely from the exhaust air outlets and smoke vents of other fire areas to minimize the possibility of drawing products of combustion into the plant.

3-4.2.7 Fire hazards should not be located in the principal access or air supply (e.g., conduits, shafts, tunnels) in order to avoid loss of fresh air in the event of a fire.

3-5 Drainage.

3-5.1

Provisions should be made in all fire areas of the plant for removal of all liquids directly to safe areas or for containment in the fire area without flooding of equipment and without endangering other areas. (*See Appendix A of NFPA 15, Standard for Water Spray Fixed Systems for Fire Protection.*) Drainage and prevention of equipment flooding should be accomplished by one or more of the following:

(a) Floor drains.

(b) Floor trenches.

(c) Open doorways or other wall openings.

(d) Curbs for containing or directing drainage.

(e) Equipment pedestals.

(f) Pits, sumps, and sump pumps.

NOTE: Draining the space above the turbine head cover by gravity may not be possible. Both ac and dc drainage pumps discharging into piping leading to the station sump are often provided with suctions in the well where the shaft first extends above the gland seal. In addition, gravity drainage may be impossible from some of the enclosed volumes of “bulb” units. In such cases, accumulated liquids from oil spills and from fire suppression should be pumped to sumps or to other containment volumes.

3-5.2

The provisions for drainage and any associated drainage facilities (pits, sumps, and sump pumps) should be sized to accommodate all of the following:

(a) The spill of the largest single container of any flammable liquid or combustible liquid, or both, in the area.

(b) The maximum design volume of discharge from the expected number of fire hose lines operating for a minimum of 20 minutes.

(c) The maximum design volume of discharge from the fixed fire suppression system(s) operating for a minimum of 20 minutes.

NOTE: The provisions for drainage and any associated drainable facilities (pits, sumps, drains to downstream surge chamber and/or tail tunnels or tailrace, and sump pumps) for underground power plants should be sized to accommodate the discharge from the maximum expected discharge of fixed fire suppression system(s) operating for a minimum of two hours.

3-5.3

Floor drainage from areas containing flammable or combustible liquids should be trapped to prevent the spread of burning liquids beyond the fire area.

3-5.4

Where gaseous fire suppression systems are installed, floor drains should be provided with adequate seals or the fire suppression system should be sized to compensate for the loss of fire suppression agent through the drains.

3-5.5

Drainage facilities should be provided for outdoor oil-insulated transformers, or the ground should be sloped such that oil spills will flow away from buildings, structures, and adjacent transformers. Unless drainage from oil spills is accommodated by sloping the ground around transformers away from structures or adjacent equipment, consideration should be given to providing curbed areas or pits around transformers. The pit or drain system or both should be sized in accordance with 3-5.2. The curbed area or pit may be permitted to be filled with uniformly graded, crushed stone as a means of minimizing ground fires.

3-5.6

For facilities consisting of more than one generating unit, a curb or trench drain should be provided on solid floors where the potential exists for an oil spill, such that oil released from an incident on one unit will not expose an adjacent unit.

3-5.7

For environmental reasons, liquid discharges resulting from oil spills or operation of a fire suppression system may have to be treated (e.g., oil separation).

3-5.8

An emergency power supply should be provided for principal drainage pumps in situations where flooding would be dangerous.

3-6 Emergency Lighting.

3-6.1

Emergency lighting should be provided for means of egress in accordance with NFPA *101*, *Life Safety Code*.

3-6.2

Emergency lighting should be provided for critical plant operations areas.

3-7 Lightning Protection.

Lightning protection, where required, should be provided in accordance with NFPA 780, *Standard for the Installation of Lightning Protection Systems*.

Chapter 4 General Fire Protection Systems and Equipment

4-1 General Considerations.

All fire protection systems, equipment, and installations should be dedicated to fire protection purposes.

4-2 Water Supply.

4-2.1

Hydroelectric plants are commonly located in remote areas adjacent to rivers or at the base of lakes. Fire protection water supplies may be permitted to be limited to the water from the river, lake, reservoir, or private tank(s). Consideration should be given to the special problems for this type of water supply (i.e., freezing, low flow, heavy sediment) associated with requirements for the fire protection systems, equipment, and installation.

4-2.2

The water supply for the permanent fire protection installation should be based on the largest fixed fire suppression system demand plus the maximum hose stream demand of not less than 500 gpm (31.5 L/sec) for a two-hour duration.

4-2.3

If a single water supply is utilized, two independent connections should be provided. If a situation can arise in which the primary water supply can become unavailable (e.g., dewatering of penstocks), an auxiliary supply should be provided. Each supply should be capable of meeting the requirements in 4-2.2.

4-2.3.1 Where multiple fire pumps are required, the pumps should not be subject to a common failure, electrical or mechanical, and should be of sufficient capacity to meet the fire flow requirements determined by 4-2.2 with the largest pump out of service.

4-2.3.2 Fire pumps should be automatic starting with manual shutdown. The manual shutdown should be at the pump controllers only. (*See NFPA 20, Standard for the Installation of Centrifugal Fire Pumps.*)

NOTE: For unattended stations, see Section 4-9.

4-2.3.3 If tanks are of dual-purpose use, a standpipe or similar arrangement should be provided to dedicate the amount determined by 4-2.2 for fire protection use only. (*See NFPA 22, Standard for Water Tanks for Private Fire Protection.*)

4-2.3.4 Where tanks are used, they should be filled from a source capable of replenishing the 2-hour supply for the fire protection requirement in an 8-hour period. The 8-hour (time) requirement for refilling may be permitted to be extended if the initial supply exceeds the minimum storage requirement on a volume per time ratio basis. It is normally preferred for the refilling operation to be accomplished on an automatic basis.

4-2.4

Each water supply should be connected to the station supply main by separate connections, arranged and valve controlled to minimize the possibility of multiple supplies being impaired simultaneously.

4-2.5

In some rivers and tributaries, the existence of microorganisms limits the use of raw water for fire protection without treatment. Consideration of water quality can prevent long-term problems relating to fire protection water supply.

4-2.6

Upstream water is frequently the fire protection water supply. Water for fire suppression should not be taken downstream from any closure device in a penstock, flume, or forebay.

4-3 Valve Supervision.

All fire protection water system control valves should be under a periodic inspection program (*see Chapter 2*) and should be supervised by one of the following methods:

(a) Electrical supervision with audible and visual signals in the main control room or other constantly attended location.

(b) Locking valves open. Keys should be made available only to authorized personnel.

(c) Sealing of valves. This option should be followed only when valves are within fenced enclosures under the control of the property owner.

4-4 Supply Mains and Hydrants.

4-4.1

Supply mains and fire hydrants should be installed on the plant site. (*See NFPA 24, Standard for the Installation of Private Fire Service Mains and Their Appurtenances.*)

4-4.1.1 Remotely located plant-related facilities should be reviewed on an individual basis to determine the need for fire protection. If excessively long extensions of underground fire mains are necessary for fire protection at these locations, it may be permitted to supply this need from an available service main in the immediate area.

4-4.1.2 The supply mains should be looped and of sufficient size to supply the flow requirements determined by 4-2.2 to any point in the loop considering the most direct path to be out of service. Pipe sizes should be designed to encompass any anticipated expansion and future water demands.

4-4.1.3 Indicator control valves should be installed to provide adequate sectional control of the fire main loop to minimize plant protection impairments.

4-4.2

Each hydrant should be equipped with a separate shutoff valve located on the branch connection to the supply main.

4-4.3

It may be necessary for the fire department to draft from the river or lake adjacent to the plant. However, the terrain and elevation above the water supply may make it difficult for drafting. Consideration should be given to installing a dry hydrant with adequate fire apparatus access that will take suction from the river above the hydroelectric plant.

4-5 Standpipe and Hose Systems.

4-5.1

Standpipe and hose systems should be installed. (*See NFPA 14, Standard for the Installation of Standpipe and Hose Systems.*) The standpipe and hose system is an extension of the fire main and hydrant system. The hose stations should be capable of delivering the hose stream demand for the various hazards in buildings.

4-5.2

Fire main connections for standpipes should be arranged so that a fire main break can be isolated without interrupting service simultaneously to both fixed protection and hose connections protecting the same hazard or area. For the important hazards the arrangement should permit operation of at least two hose lines on a fire. For areas of high water demand, the installation should meet the requirements for a Class III system. (*See NFPA 14, Standard for the Installation of Standpipe and Hose Systems.*) For other areas, a Class II system may be permitted to suffice.

4-5.3

The standpipe piping should be capable of providing minimum volume and pressure for the highest hose stations.

4-5.4

Due to the open arrangement of these plants, the locations of hose stations should take into account safe egress for personnel operating hose lines.

4-5.5

Spray nozzles having shutoff capability and listed for use on electrical equipment should be provided on hoses located in areas near energized electrical equipment.

4-5.6 Hose Threads.

Hose threads on hydrants and standpipe systems should be compatible with fire hose used by the responding fire departments.

4-6 Portable Fire Extinguishers.

For first aid fire protection, suitable fire extinguishers should be installed in accordance with NFPA 10, *Standard for Portable Fire Extinguishers*.

4-7 Fire Suppression Systems and Equipment — General Requirements.

4-7.1

Fire suppression systems and equipment should be provided in all areas of the plant as identified in Chapter 5 or as determined by the Fire Risk Evaluation. Fixed suppression systems should be designed in accordance with the following codes and standards unless specifically noted otherwise:

NFPA 11, *Standard for Low-Expansion Foam*

NFPA 11A, *Standard for Medium- and High-Expansion Foam Systems*

NFPA 12, *Standard on Carbon Dioxide Extinguishing Systems*

NFPA 12A, *Standard on Halon 1301 Fire Extinguishing Systems*

NFPA 13, *Standard for the Installation of Sprinkler Systems*

NFPA 15, *Standard for Water Spray Fixed Systems for Fire Protection*

NFPA 16, *Standard for the Installation of Deluge Foam-Water Sprinkler and Foam-Water Spray Systems*

NFPA 231, *Standard for General Storage*

NFPA 231C, *Standard for Rack Storage of Materials.*

4-7.2

The selection of extinguishing agent should be based on:

(a) Type of hazard.

(b) Effect of agent discharge on equipment.

(c) Health hazards.

NOTE: Personnel hazards created by the discharge of CO_2 should be considered in the design of the system. The design should take into account the immediate release of CO_2 into the protected area and the possibility of CO_2 leakage, migration, and settling into adjacent areas and lower elevations of the plant. See NFPA 12, *Standard on Carbon Dioxide Extinguishing Systems*, for hazards to personnel. As a minimum, if CO_2 systems are provided, they should be provided with an odorizer for alerting personnel, and breathing apparatus should be provided for operators in areas that cannot be abandoned.

4-7.3 Fire Suppression System Safety Considerations.

It is imperative that safety in the use of any fire suppression system be given proper consideration and that adequate planning be done to ensure safety of personnel.

Potential safety hazards could include impingement of high velocity discharge on personnel, loss of visibility, hearing impairment, reduced oxygen levels that will not support breathing, toxic effects of the extinguishing agent, and electric conductivity of water-based agents.

NFPA standards for the extinguishing systems used should be carefully studied and the personnel safety provisions followed. Evacuation of a protected area is recommended before any special extinguishing system discharges. Alarm systems that are audible above machinery background noise, or that are visual or olfactory or a combination, should be used where appropriate. Personnel warning signs are necessary. (*See NFPA 12, Standard on Carbon Dioxide Extinguishing Systems, and NFPA 12A, Standard on Halon 1301 Fire Extinguishing Systems.*)

4-8 Fire Signaling Systems.

4-8.1

Fire detection and automatic fixed fire suppression systems should be equipped with local audible and visual signals with annunciation in the main control room or another constantly attended location. (*See NFPA 72, National Fire Alarm Code*.)

4-8.1.1 Audible fire alarms should be distinctive from other plant system alarms.

4-8.1.2 Special consideration should be given to alerting personnel in confined spaces, such as in scroll/spiral cases or draft tubes, that a fire alarm system has been activated.

4-8.2

Automatic fire detectors should be installed in accordance with NFPA 72, *National Fire Alarm Code.*

4-8.3

The fire signaling system or plant communication system should provide the following:

(a) Manual fire alarm devices (e.g., pull boxes or page party stations) installed in all occupied buildings. Manual fire alarm devices should be installed for remote yard hazards as identified by the Fire Risk Evaluation.

(b) Plant-wide audible fire alarm or voice communication systems, or both, for purposes of personnel evacuation and alerting of plant emergency organization. The plant public address system, if provided, should be available on a priority basis.

(c) Two-way communications for the plant emergency organization during emergency operations.

(d) Means to notify the public fire department.

4-9 Unattended Plants.

4-9.1

Hydroelectric plants that are operated unattended, or with minimal staffing, present special fire protection concerns.

4-9.2

Consideration should be given both to the delayed response time of the fire brigade or public fire-fighting personnel (which can be several hours) and to the lack of personnel available to alert others on site to a fire condition.

4-9.3

The Fire Risk Evaluation should address delayed response and lack of communication. This may establish the need to provide additional fire protection measures to prevent a major fire spread prior to the arrival of fire-fighting personnel. The delayed response by personnel to the site may necessitate automatic shutoff of fire pumps.

4-9.4

If automatic water-based fire suppression systems are utilized, a cycling deluge valve should be considered. The arrangement will depend on the type of system and the hazard protected. Thermal detection is recommended. (System design should be in accordance with NFPA 13, *Standard for the Installation of Sprinkler Systems*, or NFPA 15, *Standard for Water Spray Fixed Systems for Fire Protection*.)

4-9.5

Remote annunciation of the fire signaling panel to one or more constantly attended location is critical for emergency response. The fire signaling panel should be located at the entry to the plant.

4-9.6

An emergency lighting system for critical operating areas that depends on batteries or fuel supplies should be manually operated from a switch at the entry to the plant. The emergency lighting may be permitted to consist either of fixed units or of portable lights. (*See 3-6.2.*)

4-9.7

It is important that the responding fire brigade or public fire-fighting forces be familiar with access, plant fire protection systems, emergency lighting, specific hazards, and methods of fire control. This should be reflected in the plant fire emergency plan. (*See Section 2-7.*)

4-9.8

The air supply and exhaust systems for the plant should be automatically shut down in the event of a fire. Manual override should be located at the entry to the plant so that emergency responders can activate these controls upon arrival.

Chapter 5 Identification and Protection of Hazards

5-1 General.

The identification and selection of fire protection systems should be based on the Fire Risk Evaluation. This chapter identifies fire and explosion hazards in hydroelectric generating stations and specifies the recommended protection criteria unless the Fire Risk Evaluation indicates otherwise.

5-2 Turbine-Generator Hydraulic Control and Lubricating Oil Systems.

5-2.1 Hydraulic Control Systems.

5-2.1.1 Hydraulic control systems should use a listed fire-resistant fluid.

5-2.1.2 Determination of the need for fire-resistant fluid should be based on the quantity of fluid involved in the system, whether or not equipment that utilizes this fluid will operate hot or be exposed to external sources of ignition, and whether exposure problems are created for adjacent equipment by the use of nonfire-resistant fluid.

5-2.1.3 If a listed fire-resistant fluid is not used, hydraulic control equipment should be protected. Fire extinguishing systems, where installed for hydraulic control equipment, should include protection for reservoirs, other equipment, valves, and associated piping.

5-2.2

Wherever possible, oil piping should be welded and flanged to minimize the possibility of an oil leak due to severe vibration.

5-2.3

Oil piping should be routed away, or be shielded from, electrical equipment or other sources of ignition.

5-2.4

Fixed fire protection for this equipment, where provided, should be as follows:

(a) Automatic wet pipe sprinkler systems utilizing a design density of 0.25 gpm/ft^2 (0.17 $L/sec\text{-}m^2$) for the entire hazard area (*see 3-5.3*).

(b) Automatic foam-water sprinkler systems providing a density of 0.16 gpm/ft^2 (0.11 L/sec-m^2).

(c) Gaseous extinguishing systems of either the local application or total flooding types. Safety considerations associated with these extinguishing agents should be evaluated prior to the selection of gas-type protection systems.

NOTE: When areas or rooms are located beneath areas protected by CO_2 (or other extinguishing gases), consideration should be given in the design for the possible settling of the gas to lower levels and its effect on personnel who may be in these areas.

5-2.5

Consideration for protection of horizontal and vertical turbine bearings should be made based on the Fire Risk Evaluation.

5-2.6

Curbs [minimum 6 in. (0.15 m) high] or drains or both should be provided for the oil storage and oil purification areas in accordance with Chapter 3.

5-2.7

Fire extinguishing systems, where installed for lube oil systems employing combustible-type oil, should include protection for the reservoirs, pumps, and all oil lines, especially where unions exist on piping and beneath any shielded area where flowing oil can collect. Facilities not provided with curbs or drains should extend coverage for a distance of 20 ft (6 m) from the oil lines, when measured from the outermost oil line.

5-2.8

Clean or dirty oil storage areas should be protected based on the Fire Risk Evaluation. This area generally represents the largest concentrated oil storage in the plant. The designer should consider, as a minimum, the installation of fixed automatic fire protection systems, and the ventilation and drainage requirements in Chapter 3.

5-3 Generator Windings.

5-3.1

Protection of generator windings should be provided by gaseous extinguishing systems, waterspray rings, or both. Consideration for protection should be given to the composition of the winding insulation and the rating of the generator.

5-3.2

Gaseous suppression systems should be actuated by protective relays or fire detection systems or both.

5-3.3

Waterspray rings should be manually actuated or automatically actuated by an interlocked system that requires the unit to be tripped.

5-4 Control, Computer, and Communication Rooms.

5-4.1

Control, computer, and telecommunication rooms should meet applicable requirements of NFPA 75, *Standard for the Protection of Electronic Computer/Data Processing Equipment*.

5-4.2

A smoke detection system should be installed throughout these rooms including walk-in-type consoles, above suspended ceilings where combustibles are installed, and below raised floors. Where the only combustibles above the false ceiling are cables in conduit and the space is not used as a return air plenum, smoke detectors may be permitted to be omitted from this area.

5-4.3

A preaction sprinkler system for the computer or telecommunications rooms should be considered during the Fire Risk Evaluation. In addition, gaseous extinguishing systems should be considered for areas beneath raised floors that contain cables or for areas or enclosures containing equipment that is of high value or is critical to power generation. Individual equipment or cabinet protection could be considered in lieu of total flooding systems.

5-4.4

Cable raceways not terminating in the control room should not be routed through the control room.

5-5 Cable Concentrations.

5-5.1

Consideration should be given to the use of fire-retardant cable insulation such as the types that pass the flame propagation test of the Institute of Electrical and Electronics Engineers (IEEE-383).

5-5.2

Areas with significant concentrations of combustible cable jacketing or oil-filled cable should be protected with automatic sprinkler or water spray systems. However, if water-type systems cannot be used, foam or gaseous extinguishing systems should be provided.

5-5.3

Sprinkler or water spray systems should be designed for a density of 0.30 gpm/ft^2 (0.20 L/sec-m^2) over 2500 ft^2 (232 m^2). This coverage is for area protection. Individual cable tray tier coverage could be required based on the Fire Risk Evaluation.

5-5.4 Cable with Fire-Retardant Coatings.

5-5.4.1 A suitable alternative for combustible jacket cable automatic protection would be cable with fire-retardant coatings. The method of protection should be based on the Fire Risk Evaluation.

5-5.4.2 Care should be exercised in selection of fire-retardant coatings to ensure that derating of the cable is considered. Consideration should also be given to the ability to add or remove cables and to make repairs to cables protected with fire-retardant coatings.

5-5.5

Grouped electrical cables should be routed away from exposure hazards or protected as required by the Fire Risk Evaluation. In particular, care should be taken to avoid routing cable trays near sources of ignition or flammable or combustible liquids. Where such routing is unavoidable, cable trays should be designed and arranged to prevent the spread of fire.

5-6 Cable Tunnels.

5-6.1

Where protection is required by the Fire Risk Evaluation, cable tunnels should be protected by automatic water spray, automatic wet pipe sprinkler, or foam systems. Automatic sprinkler systems should be designed for a density of 0.30 gpm/ft^2 (0.20 L/sec-m^2) over 2500 ft^2 (232 m^2) or the most remote 100 linear ft (30 m) of cable tunnel up to 2500 ft^2 (232 m^2).

5-6.2

Portable high-expansion foam generators may be permitted to be used to supplement fixed fire protection system(s). (*See NFPA 11C, Standard for Mobile Foam Apparatus.*)

5-6.3

Ventilation and drainage should be provided for these areas in accordance with Chapter 3.

5-7 Transformers.

Oil-filled main, station service, and startup transformers should be protected with automatic water spray or foam-water spray systems.

5-8 Indoor Oil-Filled Electrical Equipment.

Automatic sprinkler, foam-water, and water spray systems should be considered for oil-filled electrical equipment. Where the hazard is not great enough to warrant a fixed fire suppression system, automatic fire detection should be considered. (*See 4-8.2.*)

5-9 Battery Rooms.

Battery rooms should be provided with ventilation to limit the concentration of hydrogen to one percent by volume. For further information, refer to ANSI/IEEE 484, *Recommended Practice for Installation Design and Installation of Large Lead Storage Batteries for Generating Stations and Substations*.

5-10 Switchgear and Relay Rooms.

Switchgear rooms and relay rooms should be provided with smoke detection systems.

5-11 Emergency Generators.

5-11.1

The installation and operation of emergency generators should be in accordance with NFPA 37, *Standard for the Installation and Use of Stationary Combustion Engines and Gas Turbines*.

5-11.2

Emergency generators located within main plant structures should be protected by automatic sprinkler, water spray, foam-water sprinkler, or gaseous-type extinguishing systems. Sprinkler and water spray protection systems should be designed for a 0.25 gpm/ft^2 (0.17 L/sec-m^2) density over the fire area.

5-11.3

Where gaseous suppression systems are used on combustion engines, which can be required to operate during the system discharges, consideration should be given to the supply of engine combustion air and outside air for equipment cooling.

5-12 Air Compressors.

Automatic sprinkler protection, with a density of 0.25 gpm/ft^2 (0.17 L/sec-m^2) over the postulated oil spill, should be considered for air compressors containing a large quantity of oil. Where the hazard is not great enough to warrant a fixed fire suppression system, automatic fire detection should be considered. (*See 4-8.2.*)

5-13 Hydraulic Systems for Gate and Valve Operators.

Hydraulic control systems should use a listed fire-resistant fluid. Automatic sprinkler protection designed for a density of 0.25 gpm/ft^2 (0.17 L/sec-m^2) over the fire area should be considered for hydraulic systems not using a listed fire-resistant fluid. Where the hazard is not great enough to warrant a fixed fire suppression system, automatic fire detection should be considered. (*See 4-8.2.*)

5-14 Fire Pumps.

Rooms housing diesel-driven fire pumps should be protected by automatic sprinkler, water spray, or foam-water sprinkler systems. If sprinkler and water spray protection systems are provided they should be designed for a density of 0.25 gpm/ft^2 (0.17 L/sec-m^2) over the fire area. For automatic foam-water sprinkler systems, a density of 0.16 gpm/ft^2 (0.11 L/sec-m^2) should be provided.

5-15 Storage Rooms, Offices, and Shops.

Automatic sprinklers should be provided for storage rooms, offices, and shops containing combustible materials that present an exposure to surrounding areas that are critical to plant operations. (*For oil storage rooms, see 5-2.8.*)

5-16 Warehouses.

Automatic sprinklers should be provided for warehouses that contain high-value equipment and combustible materials that are critical to power generation or that constitute a fire exposure to other important buildings.

5-17 Auxiliary Heating.

The storage and piping systems of fuels in the gaseous or liquefied state should comply with NFPA 31, *Standard for the Installation of Oil Burning Equipment*; NFPA 54, *National Fuel Gas Code*; NFPA 58, *Standard for the Storage and Handling of Liquefied Petroleum Gases*; and NFPA 8501, *Standard for Single Burner Boiler Operation*, as applicable.

5-18 Garages.

Vehicle repair facilities should meet the requirements of NFPA 88B, *Standard for Repair Garages*.

Chapter 6 Fire Protection for the Construction Site

6-1 Introduction.

6-1.1

Although many of the activities in hydroelectric generating plant construction are similar to the construction of other large industrial plants, sites for hydroelectric generating plants are frequently located in remote areas with restricted access and limited construction space. Congested or distant construction facilities may be required, and specialized activities such as deep excavation and tunneling may be encountered. An above average level of construction fire protection is justified due to the life safety consideration of the large number of on-site personnel, high value of materials, and length of construction period.

6-1.2

Major construction projects in existing plants present many of the hazards associated with new construction while presenting additional exposures to the existing facility. The availability of the existing plant fire protection equipment and the reduction of fire exposure by construction activities are particularly important.

6-1.3

For fire protection for plants and areas under construction, see NFPA 241, *Standard for Safeguarding Construction, Alteration, and Demolition Operations.* This chapter addresses concerns not specifically considered in NFPA 241.

6-2 Administration.

6-2.1

The responsibility for fire prevention and fire protection for the entire site during the construction period should be clearly defined. The administrative responsibilities should be to develop, implement, and periodically update as necessary the measures outlined in this practice.

6-2.2

The responsibility for fire prevention and fire protection programs among various parties on site should be clearly delineated. The fire protection program that is to be followed and the owner’s right to administration and enforcement should be established.

6-2.3

The fire prevention and fire protection program should include a Fire Risk Evaluation of the construction site and construction activities at any construction camp. (*See Chapter 2.*)

6-2.4

Written administrative procedures should be established for the construction site, and such procedures should, as a minimum, be in accordance with Sections 2-4, 2-5, and 2-7.

6-2.5

Security guard service, including recorded rounds, should be provided through all areas of construction during times when construction activity is not in progress. (*See NFPA 601, Standard for Security Services in Fire Loss Prevention.*)

6-2.5.1 The first round should be conducted one-half hour after the suspension of work for the day. Thereafter, rounds should be made every hour.

6-2.5.2 Where partial construction activities occur on second and third shifts, the security service rounds may be permitted to be modified to include only unattended or sparsely attended areas.

6-2.5.3 In areas where automatic fire detection or extinguishing systems are in service, with alarm annunciation at a constantly attended location, or in areas of limited combustible loading, rounds may be permitted to be omitted after the first round indicated in 6-2.5.1.

6-2.6

Construction should be coordinated so that planned permanent fire protection systems are installed and placed in service as soon as possible, at least prior to the introduction of any major fire hazards identified in Chapter 5. In-service fire detection and fire extinguishing systems provide important protection for construction materials, storage, etc., even before the permanent hazard is present. Temporary fire protection systems may be warranted during certain construction phases. The need and type of protection should be determined by the individual responsible for fire prevention and fire protection. Construction and installation of fire barriers and fire doors should be given priority in the construction schedule.

6-3 Site Clearing, Excavation, and Tunneling.

6-3.1 Site Clearing.

6-3.1.1 Prior to clearing forest and brush covered areas, the owner should ensure that a written fire control plan is prepared and that fire-fighting tools and equipment are made available as recommended by NFPA 295, *Standard for Wildfire Control*. Contact should be made with local fire and forest agencies for current data on restrictions and fire potential and to arrange for necessary permits.

6-3.1.2 All construction vehicles and engine-driven portable equipment should be equipped with effective spark arrestors. Vehicles equipped with catalytic converters should be prohibited from wooded and heavily vegetated areas.

6-3.1.3 Fire tools and equipment should be used for fire emergencies only and should be distinctly marked.

6-3.1.4 Each site utility vehicle should be equipped with at least one fire-fighting tool, portable fire extinguisher, or backpack pump filled with 4 gal to 5 gal (15 L to 19 L) of water.

6-3.1.5 Cut trees, brush, and other combustible spoil should be disposed of promptly.

6-3.1.6 Where it is necessary to dispose of combustible waste by onsite burning, designated burning areas should be established with approval by the owner and should be in compliance with federal, state, and local regulations and guidelines. The contractor should coordinate burning with the agencies responsible for monitoring fire danger in the area and obtain all appropriate permits prior to the start of work. (*See Section 6-2.*)

6-3.1.7 Local conditions may require the establishment of fire breaks by clearing or use of selective herbicides in areas adjacent to property lines and access roads.

6-3.2 Excavation and Tunneling.

6-3.2.1 Construction activities related to tunnels, shafts, and other underground excavations are strictly regulated by federal and state agencies. Fire prevention consists of adequate ventilation, good housekeeping, and limiting the types of fuel, explosives, and combustibles underground as well as adjacent to entrances and ventilation intakes. Inspection of site conditions and the testing of air quality should be assigned to qualified personnel specifically trained in the use of those instruments specified by the regulating agency.

6-3.2.2 Pre-excavation geologic surveys should include tests for carbonaceous or oil-bearing strata, peat, and other organic deposits that can be a source of combustible dusts or explosive gases.

6-3.2.3 The use of vehicles and equipment requiring gasoline, liquefied petroleum gas, and other fuels in excavations with limited air circulation should be restricted.

6-3.2.4 A general plan of action for use in times of emergency should be prepared for every underground excavation. (*See Section 6-2.*)

6-3.3 Construction Equipment.

Construction equipment should meet the requirements of NFPA 121, *Standard on Fire Protection for Self-Propelled Mobile Surface Mining Equipment*, and NFPA 512, *Standard for Truck Fire Protection.*

6-4 Construction Warehouses, Shops, Offices, and Construction Camps.

6-4.1

All structures that are to be retained as part of the completed plant should be constructed of materials as required in Chapter 3 and should comply with other requirements of this document for the completed plant.

6-4.2

Construction warehouses, offices, trailers, sheds, and other facilities for the storage of tools and materials should be located with consideration for their exposure to major plant buildings or other important structures. These buildings should be located according to the requirements of NFPA 80A, *Recommended Practice for Protection of Buildings from Exterior Fire Exposures*, and NFPA 299, *Standard for Protection of Life and Property from Wildfire*, as applicable.

6-4.3

Mobile homes should be installed and located according to the requirements of NFPA 501A, *Standard for Fire Safety Criteria for Manufactured Home Installations, Sites, and Communities*. Insulating materials utilized in mobile homes should be noncombustible.

6-4.4

Large central office or storage facilities, where provided, should be located so as not to expose major plant buildings or other important structures. These facilities can be of substantial value, containing high value computer equipment, irreplaceable construction records, or other valuable contents, the loss of which could result in significant construction delays. The Fire Risk Evaluation may indicate a need for automatic sprinklers or other protection, the desirability of subdividing the complex to limit values exposed by one fire, or a combination of the above.

6-4.5

Construction camps comprised of mobile buildings arranged with the buildings adjoining each other to form one large fire area should be avoided. If buildings cannot be adequately separated, consideration should be given to installing fire walls between units or installing automatic sprinklers throughout the buildings.

6-4.6

Construction camp buildings should be designed and installed in accordance with NFPA *101*, *Life Safety Code*.

6-4.7

Area fire alarms should be connected to a constantly attended central location such as a fire station or site manager's office with monitoring and central alarm control. Dormitory buildings and bunkhouses should be provided with smoke detection throughout. The alarm panels for the individual buildings served should be located at the entrance to the building. Detector installation should conform to NFPA 72, *National Fire Alarm Code.*

6-4.8

The location for central alarm control should be provided with the following:

(a) Remote fire pump start button.

(b) Manual siren start/stop button.

(c) Provision for alerting the fire crew by VHF radio, fire alert paging, etc.

(d) Monitors for communication between security guard and fire crew at place of fire.

(e) Radio link between security guards' office and the respective fire department.

6-4.9

Warehouses and shops can contain materials whose loss or damage would cause a delay in startup or severe financial loss. Although some of these structures are considered to be temporary and will be removed upon completion of the plant, the fire and loss potential should be thoroughly evaluated and protection provided where warranted. Where the Fire Risk Evaluation indicates a need for protection for warehouses and shops the following guidelines should apply.

6-4.9.1 Building construction materials should be noncombustible or limited combustible. (*See Chapter 3*.)

6-4.9.2 Automatic sprinkler systems should be designed and installed in accordance with the applicable NFPA standards. Waterflow alarms should be provided and located so as to be monitored at a constantly attended location as determined by the individual responsible for fire prevention and fire protection.

6-4.9.3 Air-supported structures are sometimes used to provide temporary warehousing space. Although the fabric envelope may be a fire-retardant material, the combustibility of contents and their value should be considered, as with any other type of warehouse. Because it is impractical to provide automatic sprinkler protection for them, air-supported structures should only be used for noncombustible storage. An additional consideration is that relatively minor fire damage to the fabric envelope can leave the contents exposed to the elements.

6-4.10

Temporary enclosures, including trailers, inside permanent plant buildings should be prohibited except where permitted by the individual responsible for fire prevention and fire protection. Where the floor area of a combustible enclosure exceeds 100 ft^2 (9.3 m^2) or where the occupancy presents a fire exposure, the enclosure should be protected with an approved automatic fire extinguishing system.

6-4.11

Storage of construction materials, equipment, or supplies that are either combustible or in combustible packaging should be prohibited in main plant buildings unless:

(a) An approved automatic fire extinguishing system is in service in the storage area, or

(b) The loss of the materials or loss to the surrounding plant area would be minimal, as determined by the individual responsible for fire prevention and fire protection.

6-4.12

Construction kitchens should have automatic protection installed over the fryers. Guidance is provided in NFPA 96, *Standard for Ventilation Control and Fire Protection of Commercial Cooking Operations*.

6-4.13

Vehicle repair facilities should meet the requirements of NFPA 88B, *Standard for Repair Garages*.

6-4.14

The handling, storage, and dispensing of flammable liquids and gases should meet the requirements of NFPA 30, *Flammable and Combustible Liquids Code*, NFPA 58, *Standard for the Storage and Handling of Liquefied Petroleum Gases*, and NFPA 395, *Standard for the Storage of Flammable and Combustible Liquids at Farms and Isolated Sites*.

6-5 Construction Site Laydown Areas.

6-5.1

Fire hydrant systems with an adequate water supply should be provided in laydown areas where the need is determined by the individual responsible for fire prevention and fire protection. (*See Chapter 4*.)

6-5.2

Combustible materials should be separated by a clear space to allow access for manual fire-fighting equipment (*see Section 6-8*). Access should be provided and maintained to all fire-fighting equipment including fire hoses, extinguishers, and hydrants.

6-6 Temporary Construction Materials.

6-6.1

The use of listed pressure-impregnated fire-retardant lumber or listed fire-retardant coatings would be generally acceptable. Pressure-impregnated fire-retardant lumber should be used in accordance with its listing and manufacturer's instructions. Where exposed to the weather or moisture (e.g., draft tubes, semi-spiral cases), the fire retardant used should be suitable for this exposure. Fire-retardant coatings should not be permitted on walking surfaces or surfaces subject to mechanical damage.

6-6.2

Tarpaulins and plastic films should be of listed weather-resistant and fire-retardant materials. (*See NFPA 701*, *Standard Methods of Fire Tests for Flame-Resistant Textiles and Films*.)

6-6.3

Consideration should be given to providing sprinkler protection for combustible form work where a fire could cause substantial damage or construction delays.

6-7 Underground Mains, Hydrants, and Water Supplies.

6-7.1

Where practical, the permanent underground yard system, fire hydrants, and water supply (at least one totally reliable source of required capacity), as recommended in Chapter 4, should be installed during the early stages of construction. Where provision of all or part of the permanent underground system and water supply is not practical, temporary systems should be provided. Temporary water supplies should be hydrostatically tested, flushed, and arranged to maintain a high degree of reliability, including protection from freezing and loss of power. Where using construction water in permanent systems, adequate strainers should be provided to prevent clogging of the system by foreign objects and dirt.

6-7.2

The necessary reliability of construction water supplies, including redundant pumps, arrangement of primary and backup power supplies, and use of combination service water and construction fire protection water, should be reviewed by the individual responsible for fire prevention and fire protection.

6-7.3

Hydrants should be installed, as recommended by Chapter 4, in the vicinity of main plant buildings, important warehouses, office or storage trailer complexes, important outside structures and laydown areas with combustible construction, construction camp complexes, or combustible concrete form work (e.g., draft tube and turbine-generator blockouts). Where practical, the underground main should be arranged utilizing post indicator valves to minimize the possibility that any one break will remove from service any fixed water extinguishing system or leave any area without accessible hydrant protection.

6-7.4

A fire protection water supply should be provided on the construction site and should be capable of furnishing the largest of the following for at least a 2-hour duration:

(a) 750 gpm (47 L/sec), or

(b) The in-service fixed water extinguishing system with the highest water demand plus 500 gpm (32 L/sec) for hose streams.

NOTE 1: The highest water demand should be determined by the hazards present at the stage of construction, which may not correspond with the highest water demand of the completed plant.

NOTE 2: The water supply should be sufficient to provide adequate flow and pressure for hose connections at the highest elevation.

6-7.5

Vehicles, equipment, materials, and supplies should be placed so that access to fire hydrants and other fire-fighting equipment is not obstructed.

6-7.6

Fixed systems should be provided as soon as construction permits. These systems should be provided in continuous operating condition.

6-7.7

As fixed water extinguishing systems are completed, they should be placed in service, even when the available construction phase fire protection water supply is not adequate to meet the system design demand. The extinguishing system can at least provide some degree of protection, especially where the full hazard is not yet present. However, when the permanent hazard is introduced, the water supply should be capable of providing the designed system demand.

6-7.8

On sites where large differences in elevation exist between construction facilities, satisfying pressure requirements at the highest elevation can result in hazardous pressure conditions at the lower elevations unless some approved method of pressure regulation is included in the system. Attempting to compensate for high-pressure conditions by partially opening dry barrel hydrants can result in erosion at the hydrant thrust block and should be avoided.

6-8 Fire Suppression Systems and Equipment.

6-8.1

In general, fire suppression equipment should be:

(a) Provided where risk of fire exists.

(b) Suitable as to type and size for combating any likely fire.

(c) Protected from mechanical damage.

(d) Located for easy access at well-identified stations.

(e) Maintained in good operating condition.

(f) Protected from freezing.

6-8.2

Portable fire extinguishers of suitable capacity should be provided where:

(a) Flammable liquids are stored or handled.

(b) Temporary oil- or gas-fired equipment is used.

(c) A tar or asphalt kettle is used.

(d) Welding or open flames are in use.

(*See NFPA 10, Standard for Portable Fire Extinguishers.*)

6-8.3

First aid fire-fighting equipment should be provided. (*See NFPA 600, Standard on Industrial Fire Brigades, and NFPA 241, Standard for Safeguarding Construction, Alteration, and*

Demolition Operations.)

6-8.4

Hoses and nozzles should be available at strategic locations inside hose cabinets, hose houses, or on dedicated fire response vehicles.

6-8.5

No fire protection equipment or device should be made inoperable or used for other purposes.

6-8.6

If fire hose connections are not compatible with local fire-fighting equipment, adapters should be made available.

Chapter 7 Referenced Publications

7-1

The following documents or portions thereof are referenced within this recommended practice and should be considered part of the recommendations of the document. The edition indicated for each reference is the current edition as of the date of the NFPA issuance of this document.

7-1.1 NFPA Publications.

National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.

NFPA 10, *Standard for Portable Fire Extinguishers*, 1994 edition.

NFPA 11, *Standard for Low-Expansion Foam*, 1994 edition.

NFPA 11A, *Standard for Medium- and High-Expansion Foam Systems*, 1994 edition.

NFPA 11C, *Standard for Mobile Foam Apparatus*, 1995 edition.

NFPA 12, *Standard on Carbon Dioxide Extinguishing Systems*, 1993 edition.

NFPA 12A, *Standard on Halon 1301 Fire Extinguishing Systems*, 1992 edition.

NFPA 13, *Standard for the Installation of Sprinkler Systems*, 1994 edition.

NFPA 14, *Standard for the Installation of Standpipe and Hose Systems*, 1996 edition.

NFPA 15, *Standard for Water Spray Fixed Systems for Fire Protection*, 1990 edition.

NFPA 16, *Standard for the Installation of Deluge Foam-Water Sprinkler and Foam-Water Spray Systems*, 1995 edition.

NFPA 17, *Standard for Dry Chemical Extinguishing Systems*, 1994 edition.

NFPA 20, *Standard for the Installation of Centrifugal Fire Pumps*, 1993 edition.

NFPA 22, *Standard for Water Tanks for Private Fire Protection*, 1996 edition.

NFPA 24, *Standard for the Installation of Private Fire Service Mains and Their Appurtenances*, 1995 edition.

NFPA 30, *Flammable and Combustible Liquids Code*, 1993 edition.

NFPA 31, *Standard for the Installation of Oil-Burning Equipment*, 1992 edition.

NFPA 37, *Standard for the Installation and Use of Stationary Combustion Engines and Gas Turbines*, 1994 edition.

NFPA 51B, *Standard for Fire Prevention in Use of Cutting and Welding Processes*, 1994 edition.

NFPA 54, *National Fuel Gas Code,* 1992 edition.

NFPA 58, *Standard for the Storage and Handling of Liquefied Petroleum Gases,* 1995 edition.

NFPA 70, *National Electrical Code*, 1996 edition.

NFPA 72, *National Fire Alarm Code*, 1993 edition.

NFPA 75, *Standard for the Protection of Electronic Computer/Data Processing Equipment*, 1995 edition.

NFPA 80, *Standard for Fire Doors and Fire Windows*, 1995 edition.

NFPA 80A, *Recommended Practice for Protection of Buildings from Exterior Fire Exposures*, 1993 edition.

NFPA 88B, *Standard for Repair Garages*, 1991 edition.

NFPA 90A, *Standard for the Installation of Air Conditioning and Ventilating Systems*, 1993 edition.

NFPA 90B, *Standard for the Installation of Warm Air Heating and Air Conditioning Systems*, 1993 edition.

NFPA 96, *Standard for Ventilation Control and Fire Protection of Commercial Cooking Operations*, 1994 edition.

NFPA *101*, *Life Safety Code*, 1994 edition.

NFPA 121, *Standard on Fire Protection for Self-Propelled and Mobile Surface Mining Equipment*, 1996 edition.

NFPA 204M, *Guide for Smoke and Heat Venting*, 1991 edition.

NFPA 220, *Standard on Types of Building Construction,* 1995 edition.

NFPA 231, *Standard for General Storage*, 1995 edition.

NFPA 231C, *Standard for Rack Storage of Materials*, 1995 edition.

NFPA 241, *Standard for Safeguarding Construction, Alteration, and Demolition Operations*, 1993 edition.

NFPA 251, *Standard Methods of Tests of Fire Endurance of Building Construction and Materials*, 1995 edition.

NFPA 252, *Standard Methods of Fire Tests of Door Assemblies*, 1995 edition.

NFPA 253, *Standard Method of Test for Critical Radiant Flux of Floor Covering Systems Using a Radiant Heat Energy Source*, 1995 edition.

NFPA 255, *Standard Method of Test of Surface Burning Characteristics of Building Materials*, 1996 edition.

NFPA 256, *Standard Methods of Fire Tests of Roof Coverings*, 1993 edition.

NFPA 257, *Standard for Fire Tests of Window Assemblies*, 1996 edition.

NFPA 259, *Standard Test Method for Potential Heat of Building Materials*, 1993 edition.

NFPA 295, *Standard for Wildfire Control*, 1991 edition.

NFPA 299, *Standard for Protection of Life and Property from Wildfire*, 1991 edition.

NFPA 395, *Standard for the Storage of Flammable and Combustible Liquids at Farms and Isolated Sites*, 1993 edition.

NFPA 501A, *Standard for Fire Safety Criteria for Manufactured Home Installations, Sites, and Communities*, 1992 edition.

NFPA 512, *Standard for Truck Fire Protection*, 1994 edition.

NFPA 600, *Standard on Industrial Fire Brigades*, 1996 edition.

NFPA 601, *Standard for Security Services in Fire Loss Prevention*, 1996 edition.

NFPA 701, *Standard Methods of Fire Tests for Flame-Resistant Textiles and Films*, 1996 edition.

NFPA 780, *Standard for the Installation of Lightning Protection Systems*, 1995 edition.

NFPA 1221, *Standard for the Installation, Maintenance, and Use of Public Fire Service Communication Systems*, 1994 edition.

NFPA 1962, *Standard for the Care, Use, and Service Testing of Fire Hose Including Couplings and Nozzles*, 1993 edition.

NFPA 1972, *Standard on Helmets for Structural Fire Fighting*, 1992 edition.

NFPA 8501, *Standard for Single Burner Boiler Operation*, 1992 edition.

7-1.2 Other Publications.

7-1.2.1 ANSI Publications. American National Standards Institute Inc., 1450 Broadway, New York, NY 10018.

ANSI A14.3, *Standard for Safety Requirements for Fixed Ladders*, 1984.

ANSI A1264.1, *Safety Requirements for Workplace Floor and Well Openings, Stairs, and Railing Systems*, 1992.

ANSI Z210.1, *Metric Practice Guide*, 1993.

7-1.2.2 ASTM Publications. American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19105.

ASTM E136, *Standard Test Method for Behavior of Materials in a Vertical Tube Furnace at 750°C*, Rev A-94.

ASTM E380 (See ANSI Z210.1), 1993.

ASTM E814, *Fire Tests of Through-Penetration Fire Stops*, Rev B-94.

7-1.2.3 IEEE Publications. Institute of Electrical and Electronics Engineers, 345 East 47 St., New York, NY 10070.

IEEE 383, *Standard for Type Test of Class IE Electric Cables, Field Splices, and Connections for Nuclear Power Generating Stations*, 1974.

IEEE 484, *Recommended Practice for Installation Design and Installation of Large Lead Storage Batteries for Generating Stations and Substations*, 1987.

IEEE 634, *Testing Fire Rated Penetration Seals*.

7-1.2.4 U.S. Government Publications. U.S. Government Printing Office, Superintendent of Documents, Washington, DC 20402.

29 CFR 1910.156, *Fire Brigades*, 1986.

29 CFR 1926, *Safety and Health Regulations for Construction, Subpart S-Tunnels and Shafts, Caissons, Cofferdams, and Compressed Air*.

30 CFR 1 through 199, *Mineral Resources*.

7-1.2.5 ASHRAE Publication. American Society of Heating, Refrigerating, and Air Conditioning Engineers, Inc., 1791 Tullie Circle NE, Atlanta, GA 30329.

ASHRAE Handbook - Chapter 41, Fire and Smoke Control.

7-1.2.6 Other Publication.

Proceedings of XI International Mine Ventilation Congress.

Appendix A Explanatory Material

This Appendix is not a part of the recommendations of this NFPA document but is included for informational purposes only.

A-1-4 Approved.

The National Fire Protection Association does not approve, inspect, or certify any installations, procedures, equipment, or materials; nor does it approve or evaluate testing laboratories. In determining the acceptability of installations, procedures, equipment, or materials, the authority having jurisdiction may base acceptance on compliance with NFPA or other appropriate standards. In the absence of such standards, said authority may require evidence of proper installation, procedure, or use. The authority having jurisdiction may also refer to the listings or labeling practices of an organization concerned with product evaluations that is in a position to determine compliance with appropriate standards for the current production of listed items.

A-1-4 Authority Having Jurisdiction.

The phrase “authority having jurisdiction” is used in NFPA documents in a broad manner, since jurisdictions and approval agencies vary, as do their responsibilities. Where public safety is primary, the authority having jurisdiction may be a federal, state, local, or other regional department or individual such as a fire chief; fire marshal; chief of a fire prevention bureau, labor department, or health department; building official; electrical inspector; or others having statutory authority. For insurance purposes, an insurance inspection department, rating bureau, or other insurance company representative may be the authority having jurisdiction. In many circumstances, the property owner or his or her designated agent assumes the role of the authority having jurisdiction; at government installations, the commanding officer or departmental official may be the authority having jurisdiction.

A-1-4 Listed.

The means for identifying listed equipment may vary for each organization concerned with product evaluation, some of which do not recognize equipment as listed unless it is also labeled. The authority having jurisdiction should utilize the system employed by the listing organization to identify a listed product.

A-2-8.2

Recommendations contained in NFPA 600, *Standard on Industrial Fire Brigades*, and 29 CFR 1910, Subparts E and L, should be consulted for additional information.

Appendix B

This Appendix is not a part of the recommendations of this NFPA document but is included for informational purposes only.

Sample Fire Report

Name of company: ____

Date of fire: __________ Time of fire: __________ Operating facility: ____________

Under construction: ____

Plant or location where fire occurred: ____________________________

Description of facility, fire area, or equipment (include nameplate rating) involved: ________

____

____

Cause of fire, such as probable ignition source, initial contributing fuel, equipment failure causing ignition, etc.: ____

____

____

Story of fire, events, and conditions preceding, during, and after the fire: ______________

____

____

____

Types and approx. quantities of portable extinguishing equipment used: ________________

____

____

____

Was fire extinguished with portable equipment only? ________________________

Public fire department called? ____________ Employee fire brigade at this location? ____

Qualified for incipient fires? ______________ For interior structural fires? ______________

Was fixed fire extinguishing equipment installed? __________________________

Type of fixed extinguishing system: ______________________________________

Automatic operation: __________ , manually actuated: __________ or both: ________

Specific type of detection devices: ______________________________________

Did fixed extinguishing system control? ____________ and/or extinguish fire? ________

Did detection devices and extinguishing system function properly? ________________

If "no," why not? ____

____

Estimated direct damage due to fire: $ _________ , or between $ ____ and $ _________

Estimated additional (consequential) loss: $ ___________ Nature of additional loss: ______

____

Estimated time to complete repairs/replacement of damaged equipment/structure: ___________

Number of persons injured: ________________________ Number of fatalities: ___________

What corrective or preventive suggestions would you offer to other utilities who may have similar equipment, structures, or extinguishing systems? _______________________________

____

____

Submitted by: ______________________________ Title: ______________________________